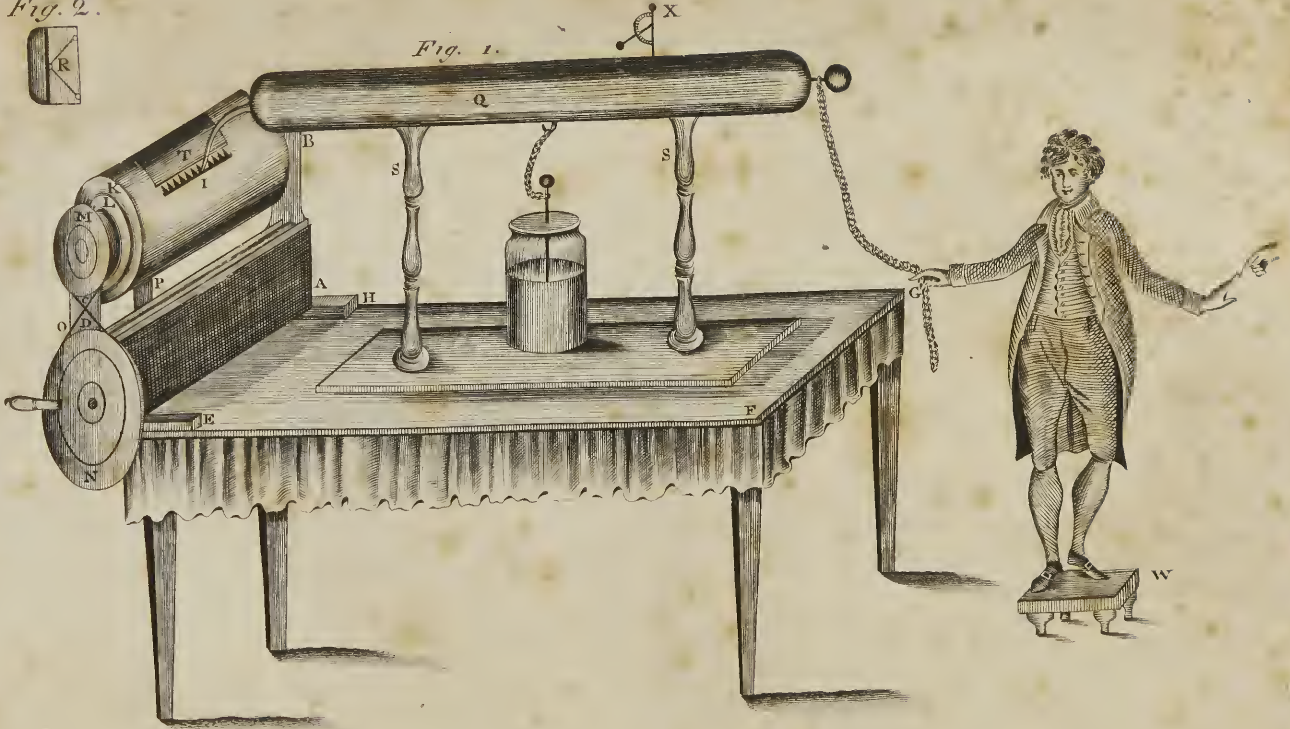
Fig. 2.

Fig. 1.



Folwell sc.

AN

EPITOME

OF

ELECTRICITY & GALVANISM.

BY TWO GENTLEMEN OF PHILADELPHIA.

Causa latet; vis est notissima.——Ovid's Met. B. IV. l. 287.

PHILADELPHIA:

PRINTED BY JANE AITKEN, No. 71,

NORTH THIRD STREET.

1809.

RECOMMENDATIONS.

HAVING perused this Epitome, it appears to me to comprise, in a concise and perspicuous manner, the principal discoveries that have been made in Electricity and Galvanism, illustrated with a variety of amusing experiments; and I have no doubt that it will prove useful and entertaining to those who wish for information on these subjects.

JOHN M'DOWELL,
Professor of Natural Philosophy, and Provost of the University of Pensylvania.

Philad. Dec. 11, 1809.

HAVING read, at the request of the authors, a work under the title of "An Epitome of Electricity and Galvanism," *I am of opinion that it is well calculated for the instruction of youth; and also that it may prove a useful manual to gentlemen who wish to acquire, without extensive reading, a general knowledge of the subjects discussed.*

JOHN MACLEAN,
Professor of Natural Philosophy and Chemistry in the College of New-Jersey.

Nassau Hall, Oct. 20, 1809.

THE Epitome of Electricity appears to me to contain a concise, but perspicuous and correct statement of the laws of that branch of Philosophy, and an interesting collection of facts and experiments, by which they are illustrated.

JEREMIAH DAY,

Professor of Mathematics and Natural Philosophy.

Yale College, Nov. 25, 1809.

[As the authors could not transmit to Professor DAY a copy of the Epitome of Galvanism, without unduly delaying the publication, his testimonial, of course, refers only to the Epitome of Electricity.]

PREFACE.

HAVING denominated the following work an epitome of Electricity and Galvanism, it seems reasonable to request that the reader should keep the nature of our plan in view. If the book do not contain, on the subjects proposed to be treated, all that is most important, let it be condemned. But let not detail be expected where the design requires conciseness. There are some articles under which we were obliged, either to omit unimportant improvements, or to occupy several pages in describing them.

Where, however, omissions of any consequence have taken place, we have endeavoured carefully to refer to the books which will supply them; so that our work may not only teach the elements and substance of the science, but direct those who wish to pursue it most extensively—We particu-

larly regretted that we could not describe a variety of electrometers.

Short as our work is, we found it, notwithstanding, scarcely practicable to avoid some repetition. In a few instances the historical and scientific parts may be observed, in a small degree, to interfere. Where history was useful to illustrate experiment, or experiment composed a part of history, we did not choose to separate what perspicuity required to be kept together. We hope, on the whole, that we do not need more indulgence in this respect, than we shall readily find, from those who are fond of the subjects which it was our business and our pleasure to investigate.

In making our epitome, we have often written without a special reference to any book; sometimes we have abridged the writings of others; sometimes we have taken paragraphs with the alteration of a few words; and sometimes we have introduced full quotations. In the latter case, we have always wished to make a distinct reference to the author quoted; and in other cases, we have generally made our acknowledgments where we

were particularly indebted. But as our work was begun without any determination to publish it, we have probably made some selections, of which we have ourselves forgotten the authors from whom they were taken. Of the fairness of a work of this nature, we suppose there can be no question. Johnson, when speaking of the system of logic published by Watts, has made our apology—"If he owes part of it to Le Clerk, it must be considered, that no man who undertakes merely to methodise or illustrate a system, pretends to be its author."

As impositions are often attempted, by soliciting patronage for publications of little value, we felt the importance of obtaining, in behalf of our work, the approbation of competent judges—The public will admit that it has been obtained; and the professional gentlemen who have favoured us with it in the most obliging and disinterested manner, will excuse our offering them this public tender of our grateful acknowledgments.

With these remarks we commit our little work to the candour of the public, conscious of having

assiduously laboured to furnish a book which, though it appeared to us to be much wanted, had not yet been written or compiled. Our views will be fully answered, if it shall be found well adapted to assist youth in their academical and philosophical studies, and at the same time, to afford amusement to men of learning, and some useful information to gentlemen of leisure.

INTRODUCTION.

SECTION I.

Electricity as known among the Ancients.

IN examining the progress of almost any branch of human knowledge, curiosity must meet with many repulses. By the time the attention of society is attracted to the accumulation of detached truths, which compose a science, it is often impossible to retrace its history. The real origin of most discoveries is obscured by antiquity, their authors have already sunk into oblivion, and important improvements are ascribed to different inventors.

Electricity is however oppressed by few of these difficulties. With the exception of some small discoveries mentioned by ancient authors, this science derives its origin and all its improvements from the two last centuries. Neither is the historian perplexed in giving every invention to its proper author. Those who cultivated

this science were commonly men of talents and condition; they pursued it with ability and perseverance; and either themselves published the result of their observations, or deposited them in those literary institutions which they found established in their country. The historian of electricity, therefore, with no extraordinary exertion of industry or talent, may fully collect and accurately arrange the materials of his work.

On the subject of electricity nothing earlier is on record than the observation of Thales, that yellow amber, when rubbed, has the property of attracting light bodies. —So struck was he with this property of amber, that he imagined it was animated.

Thales, the contemporary of Pythagoras, was born at Miletus, a city of Ionia, about six hundred years before Christ. Like all the Grecian sages, he travelled into Egypt; lived in that country a number of years; contracted friendships with the priests, then the depositories of science; and became deeply skilled in all their mysteries and learning. Returning to his own country, stored with the knowledge of the East, he was ranked as the first of the seven wise men of Greece, and became the founder of the Ionic school, as Pythagoras did of the Italic.

It may deserve remark that the same philosopher who is recorded to have observed the first phenomenon in electricity, is also said to have discovered the cause of thunder and lightning. We shall give to the curious, the remarkable passage containing this account, as we find it in Apuleius, a learned and eloquent writer of the second century, while he is rapidly enumerating the discoveries of Thales.

Thales Milesius ex septem illis sapientia memoratis viris facile præcipuus: fuit enim geometricæ penes Grajos primus repertor, *et naturæ rerum certissimus explorator*, *et astrorum peritissimus contemplator*, *maximas res parvis lineis reperit*, *temporum ambitus*, *ventorum flatus*, *stellarum meatus*, tonitruum sonora miracula, *siderum obliqua curricula*, *Solis annula reverticula; idem Lunæ vel nascentis incrementa*, *vel senescentis dispendia*, *vel delinquentis obstacula.*

"Thales the Milesian was decisively the most eminent of the seven famous sages; for he was the first inventor of geometry among the Greeks, the most judicious inquirer into nature, and the most skilful observer of the stars; he made great discoveries by small geometrical lines, the regulation of times and seasons, the theory of the winds, the course of the stars, *the wonderful causes of thunder*, the oblique motions of the planets, the

annual revolution of the sun, the reason of the increase, decrease, and eclipse of the moon."*

Though it is no where expressly affirmed that electricity was discovered by Thales to be the cause of thunder, yet when the two facts are placed together, they will furnish an additional argument to those writers who contend that the ancients knew much more than we are willing to allow them of those shining truths, which are the peculiar boast of modern ages. Nor should this early discovery, if we could admit it to be real, excite our surprise. Whatever hindrances might impede the progress of the ancients in other branches of knowledge, from the abstruse nature of the subject, or the want of necessary helps, it may rather excite our wonder, that the effects of electricity should remain so long unobserved. The electric fluid is no local or occasional agent; it is coeval with the world; its presence pervades every substance; it is the principal cause of the grandest scenes in nature, and its operations can hardly fail to show themselves wherever bodies are concerned.

From the time of Thales, there is a chasm in the history of electricity for three hundred years. Indeed, natural science of all kind appears to have languished,

*Apuleius, Floridor. page 361.

during this period. Theophrastus, who flourished 371 years before Christ, the disciple and successor of Aristotle, and he to whom the learned are indebted for the preservation of his master's works, then adds one more fact to the history of electricity.

In his treatise on stones, after speaking of the attractive power of amber, found on the coast of Liguria, he goes on to ascribe the same properties to the lapis lyncurius, the same substance now called tourmaline. "It possesses (says he) an attractive power like amber: and as they say attracts not only straws and leaves, but copper also, and iron, if in small particles.*"

These two discoveries of Thales and Theophrastus are all, on the subject of electricity, that industry has been able clearly to collect from the barren records of antiquity. Pliny indeed has observed that "amber being rubbed with the fingers, and having thereby become warmed, attracts to itself straws and dried leaves, in the same manner as the magnet does iron." He also attributes to the Lyncurium the same properties.—Solinus and Priscian, also, make similar statements. But as these are no more than what Thales and Theophrastus had remarked before, they are to be considered only as a repetition of what the preceding wri-

* Theophrast. περι λιθων.

ters had made known, not as any addition to the information possessed on this subject. In like manner it might be mentioned that Aristotle, Pliny, Oppian and Claudius, were fully acquainted with the benumbing effects produced by the touch of the Torpedo; but as they do not appear to have suspected that these effects were produced by electricity, they cannot be considered as communicating or possessing any additional knowledge in regard to this powerful agent.*

* Dr. Falconer, in a paper inserted in the "Memoirs of the Manchester Society," has endeavoured to prove by quotations from the writings of antiquity, and by much ingenious reasoning, that the ancients were not only acquainted with the electrical shock, but that it is probable even the method of drawing down lightning from the clouds, was known in very early times, and particularly to Numa Pompilius, the second king of Rome; and that his successor Tullius Hostilius perished, by his unskilful management of so dangerous a process.

Those who wish to pursue this subject, we refer to the above mentioned paper in 3 vol. Memoirs of the Literary and Philosophical Society of Manchester, page 378.

The same opinion is ingeniously defended, in a work of M. Dutens, entitled, "Origine des Decouvertes atribuees aux Modernes." Some curious quotations from the ancients, on electricity, are likewise contained in the Gentleman's Magazine for July 1785, page 522.

"To these may be added a curious passage in Signor Boccalini's advertisement from Parnassus (century 1. chap. 46,) published more than a hundred years before the date of Franklin's discovery, and in which the identity of the electric fluid and lightning is said to be revealed." Miller's Retrospect, 1 vol. page 24.

But after attentively considering all these discoveries, we cannot help acceding to the opinion of the learned President Goguet, a man who had most thoroughly investigated the origin of science among the anci-

On subjects which regard taste, or which address themselves to the imagination, on poetry, eloquence and the fine arts, it is to the ancients we are to look for information and the models of perfection. But on

ents, and we are fully persuaded that what he says of several other subjects is precisely the truth in regard to electricity.—" All (says he) which we read on this subject in the writings of the ancients, ought to be regarded as mere ideas advanced at random, without knowledge, without principles, and without any kind of foundation. If some of the ancients, for example, have said, that the earth was a spheroid, flattened at the poles ; that it revolved round the sun ; that the comets were planets, whose periodical revolutions were completed in a certain number of ages ; that the moon might be habitable ; that that planet was the occasional cause of the flux and reflux of the sea, &c.; we ought not to regard these propositions in their mouth, as the effect and the result of the knowledge which these philosophers had acquired. On the contrary, we ought to place them on the footing of those hypotheses which an uncertain and ill-regulated imagination daily produces. I say so, because none of the ancient philosophers have been able to give reasons for what they delivered ; which we may be easily convinced of, by reading the manner in which the writers of antiquity relate the opinions of their learned. There we see, that the ancients had no reasons preponderating to adopt one system rather than another ; neither were they ever able to give any of them the slightest demonstration. For the rest, I do not pretend to make this a matter of reproach to the ancients. They were destitute of all helps proper to acquire these branches of knowledge. If, nevertheless, they have sometimes hit upon the truth, we ought to attribute it to pure chance ; and be sensible, that, as they wavered in uncertainty, and ran through all possible combinations, it is not astonishing that they should hit upon the true one, because the number of these sorts of combinations is not infinite. In this respect consists the characteristical difference between the astronomical learning of the ancients and that of the moderns. What at this time we affirm of the figure of the earth, of the system of the heavens, of the cause of the flux and reflux of the sea, &c. is not the effect of chance and imagination ; it is the result of much observation, experience, and reflection, and every astronomer is able to support by reasons the system which he has thought fit to embrace."

Origin of Laws, Arts, and Sciences, Vol. III, Book III, Chap. II, Article IV.

the various branches of knowledge which depend on observation, on experiment, on investigation, which comprehend all the parts of mechanical philosophy, the philosophers of antiquity afford little that is either new or just. Hurried away by the vivacity of their genius, which their peculiar complexion invited them to cultivate, and the particular circumstances of the age were calculated to inflame, they investigated facts, not that by accumulated discoveries they might lay the foundation of solid science, but so far only as they served to support or illustrate some favourite hypothesis.

Aristotle, to whose profound and elevated genius we are accustomed to turn for satisfactory information on so many other subjects, affords no remarks on electricity, and little worthy of observation on most of the branches of natural science. One, who on this point has a right to speak, observes.—" That though there are several very sublime questions in his physics, which he clears up in a very masterly way, yet the main, the gross of the work is good for nothing, infelix operis summa.*"

From the time of Theophrastus till the beginning of the 17th century of the christian æra, there is no unequivocal evidence that in the science of electricity any discovery or improvement was made, except the soli-

* Bayle in Vita Aristot.

tary and unimportant fact that jet, and perhaps agate, is endued with the same power as amber, of attracting and repelling light bodies.—Nor is it ascertained by whom, or at what particular period, this fact was added to the slender stock of electrical knowledge which was then possessed. And thus it appears that for the space of about 1900 years, the part of philosophy, of which we trace the history, was nearly stationary.

SECTION II.

Electricity as known to the Moderns.

HAVING seen, in the preceding section, the very limited knowledge of electricity possessed by the ancients, we now come to give an account of what may properly be called its real origin, and to trace its progress to the present day. In doing this, we shall be careful to note all the original authors who have touched upon this subject; and to exhibit most of their discoveries.

We believe it to be generally the case, that, in the earlier periods of a science, the mind is curious to observe the gradual developement of principles, and the gradual increase of facts, however unimportant these facts may afterwards appear. But as the science pro-

gresses, as the ground widens and observations multiply, this curiosity proportionably abates, and we require of the historian selection rather than detail.

However minute, therefore, the history of the first stages of this branch of philosophy must be, the after periods will exact only a careful selection of those more prominent discoveries, which show the advances of the science and mark its gradations.

During the sixteenth century, the phenomena of magnetism having engaged the study of philosophers, they were naturally led to bestow some attention on substances which appeared to possess similar properties with the loadstone. Indeed, it was not till after 1729 that the idea was entertained, that electricity was a distinct fluid, or any thing else than a certain property of bodies, resembling magnetism; nor was any other meaning affixed to the word, than a power of attracting and repelling.

Fifteen centuries having elapsed from the time of Theophrastus, William Gilbert, physician to king James I, in 1600 published a latin work, entitled, *De Magnete, magnetesque corporibus*, in which, having discussed the phenomena of magnetism, he, towards the close, relates a great variety of electrical experiments.

The principal merit of this philosopher is, that he greatly augmented the list of electrical substances, noted the bodies on which electrics can act, and remarked several circumstances relating to the manner of their action.

He enumerates, as having the power of attracting light bodies, Diamonds, Saphirs, Carbuncles, Iris, Opals, Amethysts, Beryl, Crystal, Bristol-stones, Sulphur, Mastick, Hard Wax, Hard Rosin, Arsenic, Sal-gemm, Rock-Alum, common-glass, Stibium, or glass of Antimony. He also observed that the influence of these substances extended, not only to leaves and straws, but to all matter which was not extremely rare. Friction, he says, is, in general, necessary to excite the virtue of these substances; and the most effectual friction, he affirms, is that which is light and quick. Electrical appearances, he asserts, were strongest when the air was dry, and the wind north or east, at which time electrics would act ten minutes after excitation.

The simple experiments of this philosopher were mostly made with long thin pieces of metal, and other substances freely suspended on their centers, to the extremities of which he presented the electrics he had excited.

The phenomena of magnetism were accounted for, in the time of Gilbert, by means of emanating effluvia, and he applies the same theory to the explanation of electrical attraction, imagining it to be performed in the same manner as the attraction of cohesion. Two drops of water, rush together when they are brought into contact, and electrics, he says, are virtually brought into contact by means of their effluvia. *Effluvia illa tenuiora concipiunt et amplectuntur corpora, quibus uniuntur, et electris tanquam extensis brachiis, et ad fontem propinquitate, invalescentibus effluviis, deducuntur.* "Those subtle effluvia continually embrace certain bodies, to which they are united, as it were by their extended electric arms; and the effluvia prevailing, the bodies are drawn to the contiguous source of the effluvia."

Gilbert has been stiled the father of modern electricity; and when we consider how little was known of the subject prior to his time, and the merit that belongs to himself, not only from his own experiments, but also from turning the attention of philosophers to a new branch of natural science, we cannot but allow that he eminently deserves the title.

Cabeus followed Gilbert, but did little else than add to the list of electrics, wax, gum elemi, Gum guaiaci, Pix Hispanica and Gypsum.

Thirty years after the publication of Gilbert's work, the celebrated Sir Kenelm Digby, in his "Treatise of the nature of Bodies," touches upon electricity: but as the age in which he lived was still busying itself with the hypothetical philosophy of Aristotle, so this philosopher in what he says of electricity, appears to be rather amusing himself in inventing theories, to explain the manner in which electric attraction is performed, than in advancing the science by new facts and experiments. His theory of electric attraction is, however, of some celebrity: it was allowed by his cotemporary Des Cartes, in his principles of philosophy, and was embraced by the chief writers of his age; though it does not differ essentially from that of Gilbert.

"Attraction (says he) is made by a tenuious emanation, or continued effluvium, which after some distance retracteth into itself, as is observable in drops of syrups, oil and seminal viscosities, which spun at length, retire to their dimensions. Now these effluviums advancing from the body of an electric, in their return do carry back the bodies whereon they have laid hold, within the sphere or circle of their continuities; and these they do not only attract, but with their viscous arms, hold fast a good while after. And if any shall wonder why these effluvium issuing forth, impel and protrude not the straw before they can bring it back; it is because the

effluvium passing out in a smaller thread, and more enlengthened filament, stirreth not the bodies interposed; but returning into its original, falls into a closer substance and carrieth them back into itself."

Sir Thomas Brown succeeded to Sir Kenelm Digby. In his "Inquiry into Vulgar Errors," this inquisitive philosopher has a chapter on electricity, in which he corrects some mistakes into which his predecessor had fallen, adds some new experiments of his own, and gives us a summary view of the state of electrical knowledge at the time he wrote.

"By electrical bodies, (says he) I understand not such as are metallical, mentioned by *Pliny*, and the ancients; for their *electrum* was a mixture made of gold, with the addition of a fifth part of silver; a substance now as unknown as true *Aurichalcum*, or *Corinthian* brass, and set down among things lost by *Pancirollus*. Nor by electric bodies do I conceive such only as take up shavings, straws, and light bodies, in which number the ancients only placed *Jet* and *Amber*; but such as conveniently placed unto their objects attract all bodies palpable whatsoever. I say conveniently placed, that is, in regard of the object, that it be not too ponderous, or any way affixed; in regard of the agent, that it be not foul or sullied, but wiped, rubbed, and excitated;

in regard of both, that they be conveniently distant, and no impediment interposed. I say, all bodies palpable, thereby excluding fire, which indeed it will not attract, nor yet draw through it; for fire consumes its effluxions by which it should attract."

Brown augmented the list of electrics, and found attraction not only in simple bodies, but in such also as were compounded. He observed, that the attractions of bodies were different. Resinous bodies, he says, attract most vigorously, and "good hard wax so powerfully, that it will convert the needle almost as actively as the loadstone. Gums easily dissolved in water, draw not at all; no metal attracts, nor wood, though never so hard and polished. "Glass, (he says,) attracts but weakly, though clear: and some slick stones, and thick glasses but indifferently."

These experiments on the electricities of bodies, he performed by means of a needle, "settled freely upon a well pointed pin, so that the electrics might be applied to it without disadvantage;" he tried them also in straws and paleous bodies, powders of wood and iron, in gold and silver foliated.

How the attraction of electrics is performed, he acknowledges is not easily determined; though, he says,

"that it is performed by effluviums is plain, and granted by most; for electrics will not commonly attract, except they grow hot and perspirable. For if they be foul and obnubilated, it hinders their effluxion; nor if they be covered, though but with linen or sarsenet, or if a body be interposed, for that intercepts the *effluvium*. If also a powerful and broad electric of wax or *anime* be held over fine powder, the atoms or small particles will ascend most numerously unto it; and if the electric be held unto the light, it may be observed that many thereof will fly, and be as it were discharged from the electric to the distance sometime of two or three inches. Which motion is performed by the breath of the *effluvium* issuing with agility; for as the electric cooleth, the projection of the atoms ceaseth."

Sir Francis Bacon in his "Physiological Remains," has inserted a catalogue of bodies attractive and not attractive; but he differs in nothing worth mentioning from his predecessors.

Mr. Boyle, who so eminently distinguished himself in the latter part of the seventeenth century, was led by the study of chemistry, to give some attention to electricity. He enlarged the catalogue of electrics; and noticed some circumstances relating to electrical attraction, which had escaped former philosophers. The elec-

trical properties of bodies he found were increased by wiping and warming them, before they were rubbed. Bodies of all kinds, he observed, were indiscriminately attracted; and this attraction he supposed took place in vacuo as well as in the open air.

Hitherto the attraction of electrics was the single phenomenon noticed by philosophers. Gilbert, even when remarking on the characteristic differences between magnetism and electricity, observes, that in magnetism there is both attraction and repulsion, but in electricity only the latter, and not the former.* Boyle made an approach to the discovery of this fact of electrical repulsion, by remarking that light bodies, as feathers &c. would cling to his fingers and other substances, after they had been attracted by electrics.

Otto Guericke, the celebrated inventor of the air pump, who was contemporary with Mr. Boyle, improved the science much farther. He made use of a sulphur globe, whirled on an axis, much in the same way with our present glass globes. He could thus excite the electricity with greater power, and try all the experiments of his predecessors to greater advantage. His was the full discovery of electric repulsion. "A body once attracted, he remarks, by an excited electric, is repel-

* Gilbert. De Magnete. Lib. 2, Cap. 2.

led by it, and not attracted again till it has been touched by some other body." In this manner he kept a feather a long time suspended in the air, above his sulphur globe. He also made another remarkable discovery, which has since been very generally overlooked; namely, that a feather, when repelled by an excited electric, always keeps the same face towards the body which repels it, as the moon does to the earth. The electric light was probably observed by Mr. Boyle in the diamond; but Otto Guericke saw it more clearly in the excitation of his glass globe, and also heard the hissing soundwhich attends it. As this light, however, was exhibited to Dr. Wall, about the same time, in a much finer manner, we shall rather give his account of it.

"I found, says he, upon swiftly drawing a well polished piece of amber in the dark, through a piece of woollen cloth, and squeezing it pretty hard with my hand, a prodigious number of little cracklings were heard, and every one of them produced a flash of light; but when the amber was drawn gently and slightly through the cloth, it produced only a light, but no crackling; but by holding one's finger at a little distance from the amber, a large crackling is produced, with a great flash of light succeeding it. And, what to me is very surprising, upon its eruption, it strikes the finger very sensibly, wheresoever applied, with a push or puff, like

wind. This light and crackling seems, in some respects, to represent thunder and lightning.

Sir Isaac Newton is the next in chronological order, who made any discovery of importance. He first observed that the electrical attraction and repulsion, penetrated through glass. It cannot but be lamented, that this great philosopher, among the vast variety of important subjects which he cultivated and improved, had not applied himself to electricity, with greater assiduity.

Mr. Hawksbee, in 1709, wrote a treatise on electricity, and distinguished himself by discoveries which far surpassed those of his predecessors. Besides a variety of new facts in regard to attraction and repulsion, he observed the electric light distinctly, and made some delicate and curious experiments on its nature.

The electric light was considered by Mr. Hawksbee, as well as by all those who first observed it, as a species of phosphorus, and all the experiments made, were conducted under this impression.

Holding an exhausted globe within the effluvia of an excited one, he observed a light in the former, which presently died away, if it was kept at rest ;

but was revived, and continued very strong, if the exhausted globe was kept in motion. The greatest electrical light he produced, was when he enclosed an exhausted cylinder within one not exhausted, and excited the outermost of them, putting them both in motion. He observed no difference, whether the globes were turned in the same direction, or otherwise.

He made many experiments to shew the extreme subtlety of the electric light, and found out a method of rendering opaque bodies transparent. He lined with sealing wax more than half the inside of a glass globe, and having exhausted it, put it in motion. On applying his hand to excite it, he saw the shape and figure of all the parts of his hand distinctly and perfectly, on the concave superficies of the wax within. It was as if there had been pure glass, and no wax interposed between the glass and his hand. This lining was in many places the eighth of an inch thick; and in some places where it did not adhere so closely to the glass as in others, yet the light on these appeared just as on the rest. He repeated these experiments with pitch instead of sealing wax, and with equal success. It is to be regretted that these facts have not engaged more of the attention of philosophers.

After the death of Mr. Hawksbee, twenty years elapsed before any farther improvements were made. The great discoveries which were then making in other branches of philosophy, by Sir Isaac Newton, so absorbed the public attention, that electricity was entirely overlooked. Mr. Grey, after this long interval, took up the subject, and by his discovery of the distinction between electrics and non-electrics, formed an important epoch in the history of electricity.

An account of this discovery of Mr. Grey, is thus abridged from the Philosophical Transactions, by Dr. Priestley. "In the month of February 1729, Mr. Grey, after some fruitless attempts to excite an electric power in metals, recollected a suspicion he had for some time entertained, that as a glass tube, when excited in the dark, communicated its light to various bodies, it might at the same time possibly communicate to them an electricity; that is, a power of attracting light bodies; which, as yet, was all that was understood by the word *electricity*. For this purpose he provided himself with a glass tube, three feet five inches long, and near one inch and two-tenths in diameter. To each end was fitted a cork; to keep the dust out when the tube was not in use. His first experiments were made with a view to determine whether a tube would attract equally well with the ends shut, as with them open.

In this respect there was no difference; but he found that the corks attracted and repelled light substances, as well, and rather better than the tube itself. He then fixed an ivory ball upon a stalk of fir about four inches long, and thrusting the end of the stalk into one of the corks, he found the ball endowed with a strong attractive and repulsive virtue. This experiment he repeated in many different ways; fixing the ball upon long sticks, and upon pieces of brass and iron wire, always with the same success; but he constantly observed, that the ball at the end attracted more vigorously, than that part of the wire nearest the tube.

"The inconvenience of using long wires in this manner, put Mr. Grey upon trying whether the ball might be suspended by a pack-thread, with a loop on the tube, with equal success; and the event fully answered his expectation. Having thus suspended bodies of the greatest length he conveniently could, to his tube, he ascended a balcony 26 feet high, and fastening a string to his tube, found that the ball would attract light bodies on the ground below. This experiment succeeded in the greatest heights to which he could ascend; after which, he attempted to carry the electricity horizontally. His first attempt miscarried, because he suspended his line, which was intended to carry the electricity horizontally, by a pack-thread; and thus the fluid got off from it;

but though Mr. Grey knew this was the case, he could not at any time think of any method to prevent it.

"On the 30th June 1729, Mr. Grey paid a visit to Mr. Wheeler, in order to give him a specimen of his experiments; but told him of the unsuccessful attempt he had made to carry the electric fluid horizontally; Mr. Wheeler proposed to suspend the conducting line by *silk* instead of *pack-thread*. For this advice he could give no reason, but that the silk thread was *smaller* than the other; however, with it they succeeded perfectly well. Their first experiment was in a matted gallery at Mr. Wheeler's house, on the 2d of July 1729. About four feet from the end of the gallery they fastened a line across the place. The middle of this line was silk, the rest pack-thread. Over the silken part they laid one end of the conducting line, to which was fastened the ivory ball, and which hung down about nine feet below the line stretched across the gallery. The conducting line was about 80 1-2 feet in length, and the other end of it was fastened by a loop to the electric tube. Upon rubbing the tube, the ivory ball attracted and repelled light substances, as the tube itself would have done. They next contrived to return the line, so that the whole length of it amounted to 147 feet; which also answered pretty well. But suspecting that the attraction would be stronger, without

doubling or returning the line, they made use of one carried straight forward, for 124 feet; and as they expected, found the attraction in this manner, stronger than when the lines had been doubled. Thus they proceeded with their experiments; still adding more conducting line, till at last their silk string broke with the weight. This they endeavoured to supply, first with a small iron wire, and then with a brass one. The result of these experiments, however, soon convinced them, that the silk refused to conduct the electric fluid, not on account of its *smallness*, as they had supposed, but on account of some difference in the matter. The wires were smaller than the silk threads, yet the electricity was effectually carried off by them. They had recourse, therefore, to thicker lines of silk; and thus conveyed the electric matter to the distance of 765 feet: nor did they perceive the virtue to be at all diminished by the distance to which it was carried." In the manner in which silk was found to be a non-conductor, the same quality was also discovered in many other substances, such as hair, rosin, &c.

Mr. Grey also made many electrical experiments on fluids and animal bodies. As he knew no other method of trying whether bodies were electrified or not, but by making them raise light bodies placed under them, to put a fluid in this situation, he dissolved soap in Thames

water, and suspending a tobacco pipe, he blew a bubble at the head of it; and bringing the excited tube near the small end, he found the bubble to attract leaf brass to the height of two and of four inches.* He contrived afterwards, by a curious experiment to shew the effects of electricity upon water, in a more satisfactory manner. He filled a small cup with water higher than the brim, and when he had held an excited tube over it, at the distance of about an inch or two, he says, that if it were a large tube there would first arise a little mountain of water from the top of it, of a conical form; from the vertex of which there proceeded a light, very visible when the experiment was performed in a dark room, and a snapping noise almost like that which was made when the finger was held near the tube, but not quite so loud, and of a more flat sound. Upon this, says he, immediately the mountain, if I may so call it, falls into the rest of the water, and puts it into a tremulous and waving motion. This experiment he repeated in the sun-shine, when he perceived small particles of water thrown from the top of the mountain; and sometimes a fine stream of water would arise from the vertex of the cone, in the manner of a fountain, from which issued a fine stream or vapour, whose particles were so small as not to be seen. This last circumstance he inferred, from the under side of the tube being wet.

* Philos. Trans. abridged, Vol. 7, page 18.

And by after experiments, he found that though the cylinder of water does not always rise, yet that there is always a stream of particles thrown on the tube, and sometimes to such a degree as to become visible.

In April 1730, Mr. Grey suspended a boy on hair lines, in a horizontal position, just as all electricians had before been used to suspend their hempen lines of communication, and their wooden rods; then bringing the excited tube near his feet, he found that leaf brass was attracted by his head, with a vigour sufficient to raise it to the height of eight, and sometimes of ten inches. When the leaf brass was put under his feet, and the tube brought near his head, the attraction was small; and when the leaf brass was brought under his head, there was no attraction at all. While the boy was thus suspended, Mr. Grey amused himself with making the electricity operate on several parts of his body at the same time, and at the ends of long rods, which he made him hold in his hands, and in diversifying the experiments several other ways.

Mr. Grey continued to study electricity as long as he lived; and besides giving a set of fanciful experiments, by which he supposed he had discovered a perpetual attractive power in electrics, he, a little while before his death, entered on another course by which he hoped

he should be able to astonish the world with a new sort of planetarium. "I have lately made (says he) several new experiments upon the projectile and pendulous motions of small bodies by electricity; by which small bodies may be made to move about large ones, either in circles or ellipses, and those either concentric or excentric to the centre of the large body about which they move, so as to make many revolutions about them. And this motion will constantly be the same way that the planets move round the sun, viz. from the right hand to the left, or from west to east. But these little planets, if I may so call them, move much faster in their apogeon, than in the perigeon part of their orbits; which is directly contrary to the motion of the planets round the sun." The manner in which these experiments were made, as delivered by him on his death-bed to Dr. Mortimer, was as follows: "Place a small iron globe (said he) of an inch or an inch and a half in diameter, on the middle of a circular cake of rosin, seven or eight inches in diameter, greatly excited; and then a light body, suspended by a very fine thread, five or six inches long, held in the hand over the centre of the cake, will, of itself, begin to move in a circle round the iron globe, and constantly from west to east. If the globe is placed at any distance from the centre of the circular cake, it will describe an ellipse, which will have the same excentricity as the distance of the globe from the

centre of the cake. If the cake of rosin be of an elliptical form, and the iron globe be placed in the centre of it, the light body will describe an elliptical orbit, of the same excentricity with the form of the cake. If the globe be placed in or near one of the foci of the elliptical cake, the light body will move much swifter in the apogee, than in the perigee of its orbit. If the iron globe is fixed on a pedestal an inch from the table, and a glass hoop, or a portion of a hollow glass cylinder excited, be placed round it, the light body will move as in the circumstance mentioned above, and with the same varieties." He said, moreover, that the light body would make the same revolutions, only smaller, round the iron globe placed on the bare table, without any electrical substance to support it: but he acknowledged that he had not found the experiment succeed if the thread was supported by any thing but the human hand; though he imagined any other animal substance would have answered the purpose.

These experiments occasioned a great deal of speculation. Dr. Mortimer was the only person who was able to repeat them with success, and he only when nobody but himself was the witness. It was therefore generally supposed that both he and Mr. Grey had been deceived: but from some experiments to be related hereafter, it seems probable that the success of Mr.

Grey and Dr. Mortimer was owing to their having performed their experiments with candle-light; and the failure of the others to their having attempted them by day-light. Notwithstanding which, it is more than probable that Mr. Grey has been deceived in a number of particulars; for no motion can be performed by an artificial excitation of the electric fluid, but what is attended with much irregularity.

Not long after the discovery of Mr. Grey of the difference between conductors and non-conductors, Mr. Du Fay, a French philosopher, (for the "spirit of electricity" had passed from England to France,) discovered, what was afterwards called positive and negative electricity; or as he denominated them the vitreous and resinous electricities. "Chance (says he) has thrown in my way a principle, which casts a new light on the subject of electricity. The principle is, that there are two distinct kinds of electricity, very different from one another, one of which I call vitreous, and the other resinous electricity. The first is that of glass, rock chrystal, precious stones, hair of animals, wool and many other bodies. The second is that of amber, copal, gum lac, silk thread, paper, and a vast number of other substances. The characteristics of these two electricities is, that they repel themselves and attract each other. Thus a body of the vitreous electricity repels the vitreous, and

on the contrary attracts all those of the resinous. The resinous also repels the resinous and attracts the vitreous. This discovery of Mr. Du Fay was made in consequence of his casually observing, that a piece of leaf gold, repelled by an excited glass tube, and which he meant to chace about the room with a piece of excited gum copal, instead of being repelled by it, as it was by the glass tube, was eagerly attracted.

This doctrine of two different electricities, produced by exciting different substances, was dropped after Mr. Du Fay; and even this philosopher himself adopted at last the opinion of Dr. Franklin that the two electricities differ only in degree, and that the stronger attracts the weaker. Although many of the experiments of Mr. Grey led directly to it, yet to the French philosopher just mentioned, belongs the merit of first drawing the electrical spark from the human body.—And we cannot forbear remarking, in this place on the regular and progressive advances which the human mind makes in the investigation of science. Electrical attraction was, for a long period, the single phenomenon known to philosophers.—Repulsion was then observed to be also a property of electrics.—In the investigation of these we read of the accidental discovery of the electric light.—To this naturally succeeded, Mr. Grey's distinction between conductors and non-conductors;

and then the difference between vitreous and resinous electricities by Mr. Du Fay. We shall have to remark in the sequel of this history, how each succeeding fact and invention grew out of that which immediately preceded it.

The knowledge of electricity did not stop in France. The Germans began to labour in the same field; and with laudable success. Their success arose chiefly from the improvements they made in the electrical apparatus. The simple experiments of Gilbert, and the early electricians, were made by exciting a piece of amber or sulphur. Mr. Boyle found the electric power increased by smoothing the surface of bodies. Otto Guericke made his experiment with a *globe of sulphur*, formed by melting that substance in a hollow globe of glass, and afterwards breaking the glass from off it, little supposing that the glass itself would better have answered his intention. In 1709 Mr. Hawksbee first observed the great electric power of glass. He used a *glass globe*, which he mounted upon an axis, whirling it round, and at the same time applying his hand to it. He also, to increase the power, inclosed an exhausted cylinder within another, exciting the outermost. After Mr. Hawksbee's death, the glass globe was laid aside, and his successors confined themselves to the use of *tubes*. Mr. Boze, professor of philosophy at Wittem-

burgh, in 1742 returned to the use of the *globe*. He also added a *prime-conductor* of tin or iron, supported, at first, by a man standing on cakes of rosin, but afterwards by silken lines extended horizontally, under the conductor. Mr. Winckler, of Leipsic, to excite the globe, substituted a *cushion*, instead of the hand. The electrical *star* and the electrical *bells* were also the invention of the German philosophers. Dr. Desagulier, likewise, assisted electricians by some electrical terms. He first gave to bodies conveying electricity the name of *conductors;* and those in which electricity may be excited by heating and rubbing he calls *electrics per se.*

In 1745, the attention of Dr. Watson being attracted by the account of the Germans having fired spirits of wine, he applied himself to electricity with much assiduity, and made many valuable and curious discoveries. But though his improvements were considerable, and such as at another time would have excited interest, they were now lost amid the surprise occasioned by the most remarkable discovery that had yet been made in the whole science. This was the accumulation of the electric matter in glass bottles, and the method of giving the electric shock.

The merit of this discovery belongs to Mr. Cuneus, a native of Leyden, from whence it derives its name of

the Leyden phial.* "M. Muschenbroeck, professor in the university in that city, observing with his friends, that electrified bodies, exposed to the common atmosphere, which is always replete with conducting particles of various kinds, soon lost their electricity, and were capable of retaining but a small quantity of it, imagined, that were the electrified bodies terminated on all sides by original electrics, they might be capable of receiving a stronger power, and retaining it a longer time. Glass being the most convenient electric for this purpose, and water the most convenient non-electric, they first made

* The author of the article Electricity in the Encyclopædia, ascribes the merit of this discovery (if any merit can arise from a discovery made by accident) to Mr. Van Kleist, dean of the cathedral of Camin. On what authority he does this, we are unable to state. The following (he says) is the account of it, which the dean, on the 4th of November 1745, sent to Dr. Leiberkulm at Berlin, "When a nail, or a piece of thick brass wire, &c. is put into a small apothecary's phial, and electrified, remarkable effects follow: but the phial must be very dry, or warm. I commonly rub it over before-hand with a finger, on which I put some pounded chalk.—If a little mercury or a few drops of spirit of wine are put into it, the experiment succeeds the better. As soon as this phial and nail are removed from the electrifying glass, or the prime-conductor to which it hath been exposed is taken away, it throws out a pencil of flame so long, that with this burning machine in my hand, I have taken above sixty steps in walking about my room. When it is electrified strongly, I can take it into another room, and there fire spirits of wine with it. If while it is electrifying I put my finger, or a piece of gold which I hold in my hand, to the nail, I receive a shock which stuns my arms and shoulders."

"A tin tube, or a man, placed upon electrics, is electrified much stronger by this means, than in the common way.—When I present this phial and nail to a tin tube, which I have, fifteen inches long, nothing but experience can make a person believe how strongly it is electrified. Two thin glasses have been broken by the shock of it."

their experiments with water in glass bottles; but no considerable discovery was made, till the professor, or Mr. Cuneus, happening to hold his glass vessel in one hand, containing water, which had a communication with the prime-conductor by means of a wire, and with the other hand disengaging it from the conductor (when he imagined the water had received as much electricity as the machine could give) was surprised by a sudden shock in his arms and breast, which he had not in the least expected from the experiment."

Wonder is the effect of ignorance, and ignorance begets credulity; but when wonder and credulity are coupled with terror and surprise, we must look for a strange and mishapen progeny. The exaggerated accounts of those who first experienced the electric shock cannot but raise a smile; especially as we may ascertain their real sensations by like experiments upon ourselves.

Mr. Musehenbroeck, in a letter to Mr. Reaumur, written soon after the Leyden discovery, says; that he felt himself struck in his arms, shoulders, and breast, so that he lost his breath; and was two days before he recovered from the effects of the blow and the terror. He adds, he would not take a second shock for the kingdom of France. Mr. Allamand who tried the experiment with a common beer glass, affirmed, that he

lost the use of his breath for some moments; and then felt so intense a pain along his right arm, that he at first apprehended ill consequences from it, though it soon after went off without any inconvenicnce. But the terror of Mr. Winckler of Leipsic excceded that of all the rest. The first time he tried the Leyden experiment, he says, he found great convulsions by it in his whole body: and that it put his blood into great agitation; so that he was afraid of an ardent fever, and was obliged to use refrigerating medicines. He also felt a heaviness in his head, as if a stonc lay upon it. Twice, he says, it gave him a bleeding at the nose, to which he was not inclined; and that his wife (whose curiosity, it seems, was greater than her fcars) received the shock only twice, and found herself so weak, that she could hardly walk; and that a week aftcr, upon recovering courage to reccive another shock, she bled at the nose after taking it only oncc.

Mr. Boze, with other philosophers were, however, far from participating in the cowardicc of the professor of Leipsic. They gathered resolution to receive a number of electric shocks, as strong as they could be given. Mr. Boze, indeed, as Dr. Priestley remarks, "with a heroism worthy of Empedocles, wished he might die by thc electric shock, that the account of his death might furnish an article for the memoirs of the French

academy of sciences. But, adds the same author, it is not given to every electrician to die the death of the justly envied Richman."

This experiment, calculated, not only to engage the investigation of the philosopher, but to raise the vulgar amazement, brought electricity into general notice.—From this time every body was eager to see and to feel this prodigy of nature; and numbers of persons, travelling over Europe, gained a livelihood by exhibiting its appearances and effects. At the same time, all the electricians were zealous to search into the nature of this extraordinary phenomenon. Dr. Watson prosecuted experiments to ascertain how best to succeed with the Leyden phial. He observed that the force of the shock was not increased by the size or number of the globes employed in filling it; nor by increasing the quantity of water in the vessel; but that the power was greatest when the glass was thinnest, and the water warmer than the ambient air. He was proceeding with these discoveries, when Mr. Bevis informed him that he found the electric explosion as great from covering the sides of a pane of glass, as it could have been from a half pint phial of water. The Doctor upon this coated large jars with leaf silver, both inside and outside, within an inch of the top, and from the greatest explosion he produced from them, drew the conclusion that the effect of the

Leyden bottle was owing, not so much to the *quantities* of non-electric matter contained in the glass, as to the *number of points of non electric contact* within the glass, and the density of matter of which these points consisted.

In France, the Abbè Nollet attempted to measure the distance to which the electric shock might be carried, and the velocity with which it passes. At one time he electrified 180 of the guards in the king's presence; and at another the whole community of the grand convent of the Carthusians at Paris, forming a line of 900 toises, by means of iron wires between every two persons; when the whole company, upon the discharge of the phial, gave a sudden spring at the same instant of time, and all felt the shock equally.

But these attempts of the French philosophers to measure the electric circuit were insignificant, in comparison with the extended and numerous experiments of Dr. Watson, accompanied by a number of English gentlemen of eminence. Those gentlemen, in their first attempt, conveyed the electric shock across the river Thames; making use of the water of the river as a part of the chain of communication. This was accomplished by fastening a wire all along the Westminster bridge, at a considerable height above the water. One end of this wire communicated with the coating of a

charged phial, the other being held by an observer, who, in his other hand, held an iron rod which he dipped into the river. On the opposite side of the river stood a gentleman, who likewise dipped an iron rod into the river with one hand, and in the other held a wire the extremity of which might be brought into contact with the wire of the phial.

Upon making the discharge, the shock was felt by the observers on both sides of the river, but more sensibly by those who were stationed on the same side with the machine; part of the electric fluid having gone from the wire down the moist stones of the bridge, thereby making several shorter circuits to the phial; but still all passing through the gentlemen who were stationed on the same side with the machine.—This was, in a manner demonstrated, by some persons feeling a sensible shock in their arms and feet, who only happened to touch the wire at the time of one of the discharges, when they were standing upon the wet steps which led to the river. In one of the discharges made upon this occasion, spirits of wine were kindled by the fire which had gone through the river.

They afterwards undertook to determine whether the electric virtue could be conveyed along dry ground,

and to distinguish, if possible, the respective velocity of electricity and sound.

For this purpose, they fixed upon a hill, and made their first experiment on the 14th of August 1747; a time, when, as it happened, but one shower of rain had fallen during five preceding weeks. The wire communicating with the iron rod which made this discharge, was supported all the way upon baked sticks; as was also the wire which communicated with the coating of the phial, and the observers were distant from each other two miles. The result of the explosion demonstrated to the gentlemen present, that the circuit performed by the electric matter was four miles, viz. two miles of wire, and two of dry ground, the space between the extremities of the wires.—A distance which, without trial, as they justly observed, was too great to be credited. A gun was discharged at the instant of the explosion, and the observers had stop watches in their hands, to note the moment when they felt the shock; but, as far as they could distinguish, the time in which the electric matter performed that vast circuit might have been instantaneous.

Travellers through a new region of science, like travellers through an unexplored country, too often think themselves absolved from the strict obligations of truth,

and at liberty to amuse the public with romantic accounts of what they have heard and seen. About the time these experiments were going forward in England, the passion for the marvellous strongly discovered itself in relating some effects of electricity, pretended to be found out in Italy and Germany. It was asserted by Signor Privati of Venice, and after him by Verati at Bologna, Mr. Blanchi at Turin, and Mr. Winckler at Leipsic, that if odoriferous substances were confined in glass vessels, and the vessels excited, the odours and other medical virtues would transpire through the glass, infest the atmosphere of the conductor, and communicate their virtue to all persons in contact with it; also, that those substances, held in the hands of persons electrified, would communicate their virtues to them, so that the medicines might be made to operate without being taken into the stomach. They even pretended to have wrought many cures by the help of electricity applied in this way. It was affirmed that a man who, having a pain in his side had applied hyssop to it by the advice of a physician, approached a cylinder in which was concealed some balsam of Peru, and was electrified by it. The consequence was that when he went home and fell asleep he sweated, and the power of the balsam was so dispersed that even his clothes, the bed and chamber, all smelled of it. When he had refreshed himself by this sleep, he combed his head, and found that

the very comb was perfumed. To see the wonderful effects of these *medicated tubes*, as they were called, Mr. Nollet travelled into Italy, where he visited all the gentlemen who had published an account of these alledged facts. But though he engaged them to repeat their experiments in his presence and upon himself, and though he made it his business to get all the information he could concerning them, he returned fully convinced, that in no instance had odour been found to transpire through the pores of excited glass, and that no drugs had ever communicated their virtues to people who had only held them in their hands while they were electrified. He was convinced, however, that by continued electrification, without drugs, several persons found considerable relief in various disorders; particularly, that a paralytic person had been cured at Geneva, and that one who was deaf of an ear, another who had a violent pain in his head, and a woman with a disorder in her eyes, had been cured at Bologna: so that from this time we may date the introduction of electricity into the medical art.

Another wonderful experiment was the *beatification* of Mr. Boze; which other electricians, for a long time, endeavoured to repeat after him, but to no purpose. His description of this remarkable experiment was, that if, in electrifying, large globes were employed, and the

electrified person stood upon large cakes of pitch, a lambent flame would by degrees arise from the pitch, and spread itself around his feet; that from thence it would be propagated to his knees and body, till at last it ascended to his head; that then, by continuing the electrification, the person's head would be surrounded by a glory, such as is in some measure represented by painters in ornamenting the heads of saints. Dr. Watson took the utmost pains to repeat this experiment. He underwent the operation several times, and was supported during the time of it by solid electrics three feet high. Being electrified very strongly, he felt a kind of tingling on the skin of his head, and many other parts of his body. The sensation resembled what would arise from a vast number of insects crawling over him at the same time. He constantly observed the sensation to be the greatest in those parts of his body which were nearest to any non-electric; but no light appeared upon his head, though the experiment was several times made in the dark, and with some continuance. At last the Doctor wrote to Mr. Boze himself, and his answer showed that the whole had been a trick. Mr Boze acknowledged that he had made use of a suit of armour, which was decked with many pieces of steel, some pointed like nails, others like wedges, and some pyramidal; and that when the electrisation was very vigorous, the edges of the helmet would

dart forth rays, something like those which are painted on the heads of saints.

The identity of electricity and lightning was the next discovery that engaged the attention of philosophers; and it is a discovery of the first practical importance. We have already noticed the conjectures hazarded by the ancients, on this identity, and we may remember that Dr. Wall, in his experiments on electric light and the crackling with which electricity is emitted, notices the similarity between it, and the phenomenon of thunder and lightning. But when the experiment of the Leyden phial was known to philosophers, this analogy became much more obvious. The Abbè Nollet, after suggesting that thunder is in the hands of nature what electricity is in ours, enumerates many points of resemblance between these two powers, and then says, that meditating on these points, he concludes "that one might, by taking electricity for the model, form to ones self, in relation to thunder and lightning, more perfect and more probable ideas than what have been offered hitherto."

But though these philosophers, and many others, were struck with this similarity between the electric fluid and lightning, they did not think of any method by which their suspicions might be brought to the test of

experiment.—This was first proposed by Dr. Franklin in 1750. He had before discovered the effects of pointed bodies in drawing off the electric matter more powerfully than others. This was suggested to him by one Mr. Thomas Hopkinson, who electrified an iron ball of three or four inches diameter, with a needle fastened to it, expecting to draw a stronger spark from the point of it; but was surprised to find little or none. Dr. Franklin, improving on this hint, supposed that pointed rods of iron, fixed in the air when the atmosphere was loaded with lightning, might draw from it the matter of the thunder-bolt, without noise or danger, into the body of the earth. His account of this supposition is given by himself in the following words. "The electric fluid is attracted by points. We do not know whether this property be in lightning; but since they agree in all the particulars in which we can already compare them, it is not improbable that they agree likewise in this; let the experiment be made."

This suspicion of Dr. Franklin was verified in 1752. The most active persons in making the experiments by which it was confirmed, were two French gentlemen, Messrs. Dalibard and Delor. The former prepared his apparatus at Marly la Ville, situated five or six leagues from Paris; the other at his own house, on some of the

highest ground in that capital. Mr. Dalibard's machine consisted of an iron rod forty feet long, the lower extremity of which was brought into a centry-box, where the rain could not come; while on the outside it was fastened to three wooden posts, by long silken strings, defended from the rain. This machine happened to be the first that was favoured with a visit of the etherial fire. Mr. Dalibard himself was not at home; but, in his absence, he had entrusted the care of his apparatus to one Coissier a joiner, who had served fourteen years among the dragoons, and on whose courage and understanding he could depend. This artisan had all the necessary instructions given him; and was desired to call some of his neighbours, particularly the curate of the parish, whenever there should be any appearance of a thunder storm. At length the long expected event arrived. On Wednesday the 10th of May 1752, between two and three in the afternoon, Coissier heard a pretty loud clap of thunder. Immediately he ran to the machine, taking with him a phial furnished with a brass wire; and presenting the wire to the end of the rod, a small spark issued from it, with a snap like that which attends a spark from an electrified conductor. Stronger sparks were afterwards drawn, in the presence of the curate and a number of other people. The curate's account of them was, that they were of a blue colour, an inch and a half in length, and smelled strongly of sulphur. In ma-

king them, he received a stroke on his arm a little below the elbow; but he could not tell whether it came from the brass wire inserted into the phial, or from the bar. He did not attend to it at the time; but the pain continuing, he uncovered his arm when he went home, in the presence of Coissier. A mark was perceived round it, such as might have been made by a blow with the wire on his naked skin.

Although it appears from the foregoing statement, that the directions of Dr. Franklin began to be put in execution in France, he himself completed the demonstration of his own problem, before he heard of what was done elsewhere. An account of these experiments will be found in the scientific part of this work. Since the time of Franklin, there has been no capital discovery in electricity:—at least, no discovery of such a nature as to demand a detailed account in this portion of our work. Experiments and improvements have been made; and numerous electricians have evinced a very commendable diligence in the cultivation of this department of knowledge. But their exertions have been directed to the reason and philosophy of the phenomena already known, to the classification of the facts, and to the improvement of the apparatus. Thus Mr. Canton has given a very curious set of experiments upon the conducting power of air, to ascertain wherein

consists the distinction between the bodies which are conductors, and those which are not. Signor Beccaria, also, with the same view, experimented upon water and smoke. But what more properly belongs to history, is to mention the view, which Mr. Æpinus, of the Imperial Academy of St. Petersburgh, in the year 1759, took of the science of electricity. This gentleman, struck with the resemblance of the electrical properties of the tourmaline to the properties of a magnet, which have always been considered as the subject of mathematical discussion, fortunately remarked a wonderful similarity in the whole series of electrical and magnetical attractions and repulsions, and set himself seriously to the classification of them. Having done this with great success, and having maturely reflected on Dr. Franklin's happy thought of plus and minus electricity, and his consequent theory of the Leyden phial, he at last hit on a mode of considering the whole subject of magnetism and electricity, which bids fair for leading to a full explanation of all the phenomena; at least, as far as to enable us to class them with precision, and to predict what will be the result of any proposed treatment. The work containing this hypothesis, was published at Petersburgh, under the title of *Theoria Electritatis et Magnetismi*, and is pronounced to be "one of the most ingenious and brilliant performances of the last century." A summary view of this theory, and the princi-

ples on which it is formed, will be seen in the course of the ensuing work.

Great improvements in the electrical apparatus have likewise been made since the time of Franklin; particularly in devising methods to increase the power of electricity, and to render sensible the slightest accumulation or deficiency of the electric fluid. We shall, however, content ourselves, in the conclusion, with only mentioning the electrophorus and condenser, invented by Mr. Alexander Volta, Professor of Experimental Philosophy at Como, &c. This last instrument is honorable to its inventor, not only on account of the extensively useful purposes to which it has been and may be applied; but, likewise, because it was discovered, not casually, like most of the electrical apparatus, but in consequence of scientific deduction and reasoning.

The origin of Galvanism is so recent, that we think it unnecessary to give any other history of it, than that which will be found connected with the article in the body of our work.

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CHAP. I.

Explanation of Terms; with some general Remarks.

IF a glass tube be rubbed in the dark with a dry hand or piece of buckskin, upon applying the knuckle to it a luminous stream or spark will appear, passing from the glass to the knuckle, attended with a crackling noise: this luminous spark or stream is called electricity.* It is produced by the friction of several other substances, and was first observed on amber—Hence its name, from ηλεκτρον the greek term for amber. It is a fluid extremely subtle, abounding in all nature, and is one of her principal agents; which, though generally imperceptible, sometimes becomes the object of our sight and other senses.

A glass tube, having been rubbed and producing the appearances above described, is said to be *excited*. The

*Such is the statement usually given. It may perhaps deserve consideration whether *the cause* of this luminous spark or stream, should not, strictly speaking, be considered as the true electricity.

hand or buckskin, by which this is effected, is called the *rubber*. *Electrics* are all substances which can be made to produce the same appearances; the most perfect are glass, amber, sealing-wax, sulphur, gum lac, rosin &c. These are also called *non-conductors*, from their inability to conduct the electric fluid. *Conductors* or *non-electrics* are those bodies which cannot be excited, but have the power of transmitting electricity; such are metals, water, the bodies of animals, an imperfect vacuum, heat &c. But strictly speaking, there are no *perfect* conductors or non-conductors.

A body is said to be in its *natural state*, when it is in the same state, with respect to electricity, as the mass of the earth.

When a body has more of the electric fluid than its natural quantity, it is said to be *electrified positively*, when less, *negatively*; but neither of these cases can occur in a conductor, unless the communication between it and the earth be cut off by the *intervention of an electric or non-conductor*. When this happens, the conductor is said to be *insulated*.

It may not be amiss here to mention, that the terms *electric* or an *electric per se*, and *non-electric*, were at first made use of from an erroneous idea that only those called electrics, contained the electric matter *in their substance*, which was capable of being excited by friction, and communicated by them to those called non-electrics, and supposed to be destitute of it: for glass and other electrics, being rubbed, discovered signs of having it, by snapping on the approach of a finger or other conductor, and by attracting and repelling light bodies; while other substances could not be made to produce any such effect. It has however since been

proved by experiments, that *both* electrics and non-electrics contain this matter in their substance; but that non-electrics cannot be excited, owing to the fluid diffusing itself through them as soon as collected. These terms are therefore improper, and as the only difference is that some bodies will conduct electricity and others will not, the terms *non-conductor* and *conductor* are those which might generally be used with the most propriety in speaking on this subject; though, in conformity with custom, we shall often use *non-conductor* and *electric* as synonimous.

CHAP. II.

Electric substances; with some of the phenomena attending their excitation.

THOSE substances by which electrical phenomena may be produced, form the subject which next demands our attention; but these are so numerous that it would be vain to attempt to specify them all. Perhaps it may be doubted, whether every material substance, with the exception only of metals, water, and charcoal, may not be considered as an electric.

Some however exhibit particular phenomena more obviously than others; and hence a number of catalogues have been formed, for shewing the effects which arise when electrics are excited with different rubbers. The specification which we esteem the most complete, was formed by the ingenious Mr. Cavallo, and we shall give it in his own words.

"In the following table (says he) may be seen what electricity will be excited in different bodies, when rub-

bed with different substances. Smooth glass, for instance, will be found by this table to acquire a positive electricity, when rubbed with any substance hitherto tried, except the back of a cat: (by which I mean the skin of a cat while on the animal alive:) rough glass, (viz. glass, the polish of which has been destroyed by emery or otherwise) will be found to acquire the positive electricity, when rubbed with dry oiled silk, sulphur &c. and the negative when rubbed with woolen cloth, the hand &c. and so of the rest."

Electrics.	*Qualities.*	*Rubbers.*
"The back of a cat	Positive	Every substance with which it has hitherto been tried.
Smooth Glass.	Positive	Every substance hitherto tried, except the back of a cat.
Rough Glass	Positive	Dry oiled silk, sulphur, metals.
	Negative	Woolen cloth, quills, wood, paper, sealing wax, white wax, the human hand.
Tourmaline	Positive	Amber, or air blown upon it.
	Negative	Diamond and the human hand.
White silk	Positive	Black silk, metals and black cloth.
	Negative	Paper, hand, hare's & weasel's skin.
Black silk	Positive	Sealing wax.
	Negative	Hare's, weasel's and ferret's skin, load-stone, brass, iron, silver, hand.
Weasel's skin	Positive	Metals, silk, load-stone, leather, hand, paper, baked-wood.
	Negative	Other fine furs.
Sealing wax	Positive	Metals.
	Negative	Hare's, ferret's and weasel's skin, hand, leather, woolen cloth, paper.
Baked wood	Positive	Silk.
	Negative	Flannel."

From the above table it appears, that the powers of electric substances vary prodigiously from one another; and that, according to the different rubbers made use of, we may sometimes produce one phenomenon and some-

times another. Hence we have a foundation for classing electric substances according to the various powers they occasionally exhibit; which may be done in the following manner.

First. Those which exhibit a *strong* and *permanent* attractive and repulsive power, of which the most remarkable is silk.

Second. Those which exhibit the electric light, attraction, repulsion, and all the other phenomena of electricity in a very *vigorous*, though *not durable* manner; of these glass is eminently preferable to all others.

Third. Those which exhibit electric appearances *for any length of time*, and which communicate to conducting bodies, *the greatest electric power.*—Of these, the substances called *negative electrics*, such as sealing-wax, resinous substances, and resinous compounds, are the best.

Fourth. Those which readily exhibit electrical phenomena by *heating* and *cooling*—Of these, the tourmaline* is the principal.

The best method of disturbing the electric fluid, that is of making it pass from one body to another, is friction. This may be done either by rubbing one electric with another, or with a conductor; but the electricity is generally stronger in the latter case. Other methods for causing electrics to shew electric appearances, are,

* Tourmaline is a species of silicious earth. Its colour is generally a blackish brown, though the tourmaline of Brazil is blue, green, red, or yellow. It is a compound substance, consisting of argill, silex, calcareous earth, and iron in different proportions; but argill and silex are always the chief ingredients. It is found in Ceylon, Brazil, and Tyrol; and it is also found in large quantities in the neighbourhood of Philadelphia, attached to masses of quartz.

melting, or pouring a melted electric on another substance, heating and cooling, evaporating or effervescing.

CHAP. III.

Of Electrics and Conductors.

ALL bodies in nature are, with reference to this subject, divided into two classes, *electrics* and *conductors.*

It has been fully demonstrated by experiment, that no substance which is a conductor can be excited so as to exhibit electrical phenomena: and in the same manner it has been found, that no substance which can be excited, is a conductor. But as we have already hinted, there is, strictly speaking, no substance which is a *perfect* conductor or non-conductor; because, on the one hand, the electric fluid meets with some resistance in its passage through the best conductors; and on the other, it is in part transmitted through, or passes over the surface of, most if not all electrics.

The two following lists contain as complete an enumeration of electrics and conductors as the present state of knowledge, in regard to electricity, permits us to make.

The substances are disposed in the order of their perfection; that is, the best conductors and the best electrics are placed at the head of their respective lists, and those of an inferior kind follow, somewhat in the manner of a scale graduated downward. Perfect exactness however is not to be here expected, because the subject forbids it, and some of the specified articles are of classes of substances among which there may be a sensible difference.

Conductors or non-electrics.

Gold,
Silver,
Copper,
Platina,
Brass,
Iron,
Tin,
Mercury,
Lead,
Semi-metals.

Metalic ores—Of which those are the best which contain the greatest number of metallic parts and are nearest to a reguline state.

Charcoal, either of animal or vegetable substances—
Animal fluids,
Acids,
Saline substances,
Hot water,
Cold water,
Salt water,
All other liquids except oils,
Red hot glass,
Melted rosin,
Flame and the effluvia of flaming bodies,*

Ice and snow—but not below the temperature of 13° Fahrenheit.

Earthy and stony substances, of which the hardest are the worst.

Glass filled with boiling water,
Vapour or steam of boiling water,

* It is very remarkable that the focus of a burning glass is not a conductor of electricity.

Smoke.

All compounds which contain the above substances in different proportions, are conductors in different degrees.

Non-conductors or electrics.

Glass and all vitrifications; even those of metals.

All gems, of which the most transparent are generally the best.

All resinous substances and resinous compounds,

Amber,

Sulphur,

Baked wood—if not suffered to imbibe moisture.

All bituminous substances,

Wax,

Silk,

Cotton,

All dry animal excrescences; as feathers, hair, wool, horn, &c.

Paper,

White sugar and sugar candy,

Atmospheric air and other gasses,

Oils,

Dry and complete metallic oxyds,

The ashes of animal and vegetable substances,

All hard stones; of which the hardest are the best,

Powders not metallic.

Ice at and below the temperature of 13° of Fahrenheit's thermometer. According to Mr. Walsh's and Mr. Morgan's experiments, the Torricellian vacuum ought to be placed at the head of this list; but the singular nature of a vacuum, though a non-conductor, will hardly entitle it to the name of an electric.

CHAP. IV.

Of the electrical machine.

HAVING now explained the terms made use of in the study of electricity, and noted some of the phenomena of different electric substances, and the difference between electrics and conductors; we shall proceed to describe the *electrical machine* made use of for shewing experiments, and for exhibiting other electric phenomena to the best advantage.

The principal parts of the machine are, *the electric*, *the rubber*, the *moving engine*, and the *prime conductor*. We shall take notice of each of these parts separately and then describe the whole machine together.

Formerly different kinds of electrics were used; at present smooth glass is preferred before all others, as most convenient, and because it will, by itself, answer the purposes of several others. For when the machine has an insulated rubber, which is easily prepared, the operator may produce positive or negative electricity * at pleasure, without changing the electric.

With respect to the forms of the glass, those commonly used are globes, cylinders and plates. The most convenient size for a globe is from ten to twelve inches in diameter. It should have two necks, centrally opposite, which must be cemented † to strong caps, in order to adapt them to a proper frame. Cylinders are also made with two necks. Their common size is from six

* We do not wish to be understood that *two different* fluids may be produced, but merely, that the prime conductor may be electrified *positively* or *negatively*.

† For the proper cement, see appendix NO. I.

to seven inches in diameter, and from ten to twelve inches in length; the glass generally used is the best flint.

It has long been questioned whether a coating * of some electric substance, has any effect in increasing the power of an electric; but now it seems pretty well determined, that if it does not increase the power of a good one, it at least considerably improves a bad one.

The next thing to be considered is *the rubber* which is to excite the electric. This, as it is now made, consists of a cushion of buckskin, stuffed with hair or flannel, and fastened to a piece of wood well rounded at the edges; to this is glued a flap of Persian black silk, which goes over nearly one half of the cylinder or globe. The rubber should be supported by a small iron or brass spring, placed inside of it, as is represented edgewise by R, figure 2, in the frontispiece. This acts in a much more uniform and parallel manner than if it were placed under the cylinder. It suits any inequalities that may be on the surface of the glass, and by means of a screw may be made to press against the cylinder as occasion requires. It should likewise be insulated in the most perfect manner by glass, or by baked wood well varnished. But when experiments are to be made which do not require or admit of insulation, a communication must be made between the rubber and the earth, by a chain or conductor.

To increase the effect of the rubber several substances have been used with success, particularly whiting and pulverised chalk. But the best of all is an amalgam of zinc and mercury.† This amalgam is to be used by

* See appendix NO. II.

† See appendix NO. III.

first applying a moderate quantity to the cushion; and afterwards by spreading it on a separate piece of leather, and applying it occasionally to the under part of the cylinder while turning. In this method of using it, only a small quantity of amalgam is consumed, while the glass is very strongly excited; and by degrees the whole rubber contiguous to the cylinder is covered with amalgam, in the form of a concave cake. It is with such a rubber that the cylinder is most powerfully excited.

An ingenious friend has favoured us with the following explanation of the manner in which electrics are excited, which to us is more satisfactory than any other we have seen. "In order that electricity may be accumulated in greater quantity in one body than in the surrounding ones, it must be set in motion. This may be effected by the *rubbing of electrics;* the *juxta-position* of non-electrics of different conducting powers; and by the *chemical action* of many, if not all bodies on each other. The rubber will act on the first principle, and the more perfect the contact between it and the electric the greater will be the effect. The chalk, whiting, amalgam &c. while they will, if properly prepared, make the contact more perfect, will also be of service on the second principle; and the amalgam will besides be of use on the third. Mercury and zinc may be exposed separately to the air without any alteration; but when combined they readily unite with the oxygen of the atmosphere; especially when the surface of contact is frequently renewed, and the temperature increased by friction.

"The glass, acquiring a different state of electricity from the rubber, will, as each portion passes from under it, carry away and impart to the prime conductor

the excess which it has obtained; and this the more certainly if the dissipation of the electricity be prevented, or the accumulation increased, by a piece of silk connected with the rubber.—The chain making the communication between the rubber and the adjoining non-electrics will enable this process to go on; and perhaps may also assist on the second principle."

With respect to the engine which is to give motion to the electric, it has been customary, simply to turn the globe or cylinder with a winch; but this will not produce the greatest power of which the glass is capable. To effect this it should be made to turn six or seven times in a second, which is more than can conveniently be done with the winch only; and therefore multiplying wheels are used with advantage.

The prime or first conductor is an insulated non-electric substance, furnished with a number of points on the end towards the electric, in order to collect the electricity from it. It is usually made cylindrical, but whatever be its form it should always be perfectly free from points or sharp edges, except the points toward the electric already mentioned; and if holes are made in it, which on many accounts are very convenient, they should be well rounded and perfectly smooth.—The larger this conductor is, if not disproportionate to the cylinder or globe, the stronger and more dense will be the electric spark, which will proceed from it when touched by a blunt conductor. There must however always be a certain proportion between the cylinder or globe and the prime conductor, for if the former be small and the latter large, the electricity will not be collected fast enough, to preserve an accumulation of it in the prime conductor, because a portion is always taken

off by the air, in proportion to the surface presented to it by the conductor.

We shall now give a short connected explanation of the whole machine, a draft of which is exhibited in the frontispiece. AB and CD are two pillars of baked wood well varnished, perpendicularly raised from the top of the table EFGH—these serve to support the cylinder I, by the axles of the caps KK; from one of these proceeds the long axle L, which passes through a hole in the pillar CD, having the pulley M, fixed on its square end. N is a multiplying wheel, around which the band or strap O passes, and likewise around the pulley M.—The wheel N should be made moveable with respect to the pulley M, to accommodate the stretching of the band, or else the pulley should have a number of grooves of different radii in its circumference.

The rubber R, is fastened to a pillar of glass, or baked wood P. The pressure of the rubber may be augmented at pleasure, by means of a sliding board and tightning screw.

The prime conductor is represented by Q. It is insulated by the glass pillars SS, which support it. T represents the points which collect the electricity from the cylinder.

Cylinders and globes made for electrical machines are not always to be procured. Their place however, may be very well supplied by the large show bottles of the apothecaries. When these are used, one of the caps, instead of being concave (to receive the neck of the cylinder) must be made convex—so as to fit the hollow in the bottom of the bottle—It is to be fastened with the cement used in the other machine.

The most powerful electrical machine ever constructed, was at Teyler's museum at Haarlem. It had, instead of the cylinder or globe as in the common machines, two circular plates of glass, which were made to turn upon the same horizontal axis. These plates were excited by eight rubbers, which acted on their surfaces. In this machine the prime conductor had branches which collected the electricity from between the plates.

It is not necessary however in this form of the machine to have two plates, the second being added only to increase the power. The plate must be firmly fastened by its centre to an axis—so as to turn vertically between two uprights of baked wood, as in the construction of the cylindric machines; but in this case the uprights must be so close together, as barely to leave room for a rubber on each side of the plate. The rubbers may be made of the same form with that in the cylindric machine—except that they must have a projection at the back, to fit a niche cut in the uprights which support the plate. The power of the machine will be increased by having four rubbers; two above and two below the axis of the plate. The prime conductor is placed opposite one of the ends of the axis, and is divided at the end towards the electric into two branches or arms, which extend horizontally to the circumference of the plate, each of which is furnished with points to collect the electricity.

As plates are not always to be procured, a good substitute may be found in a thick pane of glass or a piece of an old looking-glass. Mark with a diamond or file a circle on the glass, of the size you intend for your plate. Then putting the plate into warm water, after some time cut

the glass with a diamond in tangents. The more numerous the cuts, the nearer the plate will be to a circle. A hole may be made in the centre for the axis, by scratching with a diamond, and grinding with a rod of iron (held between the hands) and emery.

CHAP. V.

Of communicated electricity.

HAVING described the electrical machine, we are now to consider some of the phenomena attending its operation. When the prime conductor receives electricity from the cylinder, it is said to be *electrified by communication*, and it then acts in every respect like the cylinder itself, except that the latter, when touched by a conductor communicating with the earth, gives a considerable number of sparks before it is discharged; whereas the conductor discharges itself by a single spark.

The cause of this difference is that the cylinder, being an electric, cannot convey the electricity of all its surface to that part, to which the conducting substance is applied; but the fluid accumulated in the whole conductor, passing easily through its substance, is transmitted at once to the point from which the discharge is made. Hence it appears that the electricity discharged from an electrified conductor is more powerful than that discharged from an electric—the conductor acquiring a large quantity of electricity from an electric, by receiving it gradually, spark after spark, and afterwards, when touched, discharging it all at once.

The velocity of electricity is almost beyond conception. It is, notwithstanding, in a small degree relative

to the quantity put in motion, and to the goodness of the conductor by which it is transmitted. A large quantity of electricity passes through a good conductor with such rapidity, that there is no perceptible difference in the time which it takes to go one foot, or one thousand feet. A small quantity however has been found to take a time barely perceptible, in passing through a long and imperfect conductor. Experiments relative to this point will be related hereafter.

CHAP. VI.

Of the electric spark.

IF a piece of metal be presented to an overcharged prime conductor, the fluid passes with violence from the one to the other; an *electric spark*, having the appearance of fire, is seen flashing between them, and a snapping noise, like the cracking of a whip, is heard. If this piece of metal be insulated, the prime conductor will be only partially discharged, that is, the redundant electricity will be divided between it and the piece of metal, nearly in proportion to their surfaces. This electric spark has not only the appearance of fire, but, when large, will actually set fire to a variety of easily inflammable substances; such as cotton sprinkled with rosin, spirits of wine &c. This power of exciting flame is not commonly believed to arise from any culinary heat in the electric spark, because if the spark be small it will not excite flame in substances the most inflammable. It acts probably by friction on the same principle as the rubbing of sticks against each other produces fire.

The electric spark, taken upon any part of a living animal, causes an unpleasant sensation, which is more or less pungent and disagreeable, as the spark is stronger or weaker, and the part more or less delicate.

There is a slight difference between the appearance of a spark taken from a body positively electrified, and that from one negatively electrified. The former, if not very long, appears straight and sharp; the latter is generally ramified, or appears in a zig-zag line.

The noise which attends the spark, is caused by the sudden agitation into which the air is thrown, by its passage through it.

CHAP. VII.

Of the influence of pointed bodies on electricity, and some phenomena attending their operation.

IF an uninsulated conductor, which is broad, round and polished at the end, be presented to the prime conductor, a short and dense spark, accompanied with some noise, will be perceived; if the conductor be less broad, the spark will be longer, less dense, and attended with less noise; if the breadth be still more diminished, so that the conductor may come under the denomination of a point, the electric matter will pass to it, from the prime conductor, and through a greater space, with a hissing noise, and in a continual stream; a still greater sharpness will enable the electricity to pass over a yet more extended space, but unaccompanied by noise, and only a small light will be seen upon the point. The same result will arise if points of different acuteness be affixed to the prime conductor, instead of

the uninsulated one: but if both be pointed, the electricity will be more readily discharged.

In all the above cases, the appearance of the electric matter at the point, will indicate the kind of electricity from which it proceeds. A large divergent cone indicates positive electricity; a small globular light, that which is negative. Hence it is always easy to ascertain whether an insulated conductor be electrified positively or negatively, by presenting a point to it, as the light at the point is always definitive of the contrary electricity in the conductor.

If a pointed conductor be electrified, either positively or negatively, and the face be brought near the point during the electrization, a wind will be felt blowing from the point, accompanied with a peculiar sensation, commonly called *the spider's web*. It is remarkable that the current of air is always in the same direction, whether the point throws off or receives electricity.

The re-action of the force, by which the air is put in motion, is exerted upon the pointed body. This is shewn by a very pleasing experiment called the electric fly. This fly is composed of four small wires, fastened into a metallic cap, similar to those used in sea-compasses, so that the wires may easily move upon a point, in a horizontal direction. They should be exactly balanced, and have their ends, which must be very sharp, all bent in the same direction. Now if this fly be placed on an insulated point and electrified, its sharp ends will become luminous in the dark, and it will revolve in a direction contrary to that in which the ends are bent; or if it be placed on an uninsulated point and brought near the electrified prime conductor, the same effect will follow.

It is to be observed, that the fly will move round in the same direction, whether electrified positively or negatively. The cause of this seeming contradiction depends upon the repulsive power existing between bodies possessed of the *same* electricity; for the air opposite to the points acquires a strong electricity, analogous to that of the points, it is therefore repelled, and replaced by other air, which is also electrified and repelled. Hence a continual stream is produced, blowing from the points, and that equally, whether the electrization be positive or negative; and as action and re-action are equal and in contrary directions, the points, repelling the air, must themselves be repelled, and in the opposite direction; which causes the fly to be always turned one way, that is, in a direction contrary to that in which the air is moved.

In vacuo no motion is produced, because there is no air on which the electric matter can act when it issues from the points.

In like manner, if air be confined in a receiver, the motion of the fly soon ceases, because the fluid cannot pass through the air and the glass. But on applying the end of a finger to the outside of the receiver, opposite one of the points of the fly, the motion will begin again, and by moving the finger occasionally round the glass, it may be continued till most of the glass is charged.

The cause of this motion is, that when the finger is applied to the outside of the receiver, the glass, loosing part of its natural quantity of electricity from that side, (i. e. when the fly is electrified positively, and vice-versa if negatively) takes up the fluid from the air on its inner surface. Hence the air becomes capable of

being again electrified by the point and this renews the motion.

We have already stated that if a pointed wire be presented to a conductor *positively* charged, it will be illuminated with a star or globe ; and if the conductor be negatively charged, the illumination will have the form of a pencil or divergent cone. F. Beccaria explains this in the following manner. I suppose, says he, that the star is occasioned by the difficulty with which the electric fluid is extricated from the air, which is an electric ; suppose for instance that a pointed wire is presented to a body positively electrified ; the electric fluid is first communicated from that body, to the air between it and the pointed wire, and then the wire must extricate it from the air.

The pencil is occasioned by the force with which the fluid, issuing from the point, passes through the contiguous air to that which is more remote, i. e. by dividing the contiguous air, and not by affixing itself to it.

Beccaria likewise remarks, that if two equally sharp pointed bodies are brought near the prime conductor, they will appear luminous at only half the distance that one of them would. They will also discharge it in half the time.

It will not be improper to remark here, that when a point *not* electrified is opposed to one electrified positively, both points will have small globular lights upon them ; but if a positive one be opposed to one negatively electrified, they both preserve their own characteristic properties.

From the above the following conclusions may be drawn.

First, That pointed bodies attract the electric matter more or less easily, and at a greater or less distance, according to their acuteness.

Second, That pointed bodies have the power of attracting electricity as well as of repelling it, in a greater degree than conductors of any other form.

We shall treat farther of pointed conductors under the article *Thunder-house.*

CHAP. VIII.

Of electric attraction and repulsion.

NO satisfactory theory of electric attraction and repulsion has, so far as our knowledge extends, ever yet been given. The phenomena have been differently accounted for, as the writers have embraced different opinions in regard to positive and negative electricity. One mode of explanation has been adopted by those who believe, with Franklin, that positive electricity is only an accumulation of the electric fluid in a body beyond its natural state; and that negative electricity is nothing more than a deficiency of this fluid in a body. Another mode of explanation is given by those who maintain, in opposition to Franklin, that positive and negative electricity are either two distinct fluids, or else vibrations of the same fluid—the positive electricity always rushing out of a body, and the negative always rushing in. Those who maintain this hypothesis endeavour to support it by the easy solution which they affirm it gives to the phenomena of electric attraction and repulsion. But after a careful examination of this theory, we think that, so far from being satisfactory, it

is scarcely intelligible. We therefore do not choose to introduce it into our epitome, as affording any solution of the difficulties that occur on this part of our subject. We are besides of opinion that the evidence in favour of a single fluid is conclusive, as we shall show when we come to discuss the theory of electricity. Yet we confess that we cannot, on this theory, offer a rationale of electric attraction and repulsion, that satisfies ourselves. It is therefore the demand of candour, and in the spirit of the Newtonian philosophy, to avow explicitly that this part of our subject is yet involved in much obscurity. In the mean time we are acquainted with certain facts, and with the clear explanation which they give of certain phenomena.

1. That bodies positively electrified, repel each other.

2. That bodies negatively electrified, also, repel each other.

3. That bodies positively electrified, attract those which are negatively electrified.

4. That bodies either positively or negatively electrified, induce a contrary electricity in bodies in their natural state, brought within the sphere of their action.

This statement is easily verified by experiment, in the following manner—By flaxen or hempen threads, suspend, from the prime conductor, two balls made of cork or elder-pith, so that they touch each other. On charging the conductor, these balls, being both electrified positively, will immediately repel each other, and be separated to a considerable distance.—Remove one of the balls, take it in your fingers, and bring it near to the one which remains positively electrified, and the two will immediately rush together; because there are now two substances of which one is electrified posi-

tively, and the other negatively—Again. Suspend two balls, of the kind just mentioned, from an insulated cushion of an electric machine, and let them touch each other. Put the machine in motion and the balls, which are now both electrified negatively, will repel each other and separate, as in the case first described.

In attempting to explain the first of these phenomena Dr. Franklin once supposed that there was an electric atmosphere round each of the balls positively electrified, the particles of which atmosphere, by mutually repelling each other, separated the balls. He also supposed that as bodies negatively electrified, or not having their proportional quantity of the electric fluid, are always strongly disposed to receive it, this would account for the fact that when one of these bodies was brought near to one that had more than its proportional quantity, the two would naturally rush together; the one to impart, and the other to receive the fluid. But at this time he was not acquainted with the fact, that two bodies negatively electrified would repel each other. When this was discovered he candidly acknowledged the utter deficiency of his theory, in regard to electric attraction and repulsion. Some of his friends and followers, however, have endeavoured still to maintain it. But we think that though their zeal has been greater, their success has not exceeded that of the Doctor himself: and we have already stated that other theories are equally, if not more defective, than that of Franklin. Let us then leave the explanation of electric attraction and repulsion to be made when future and fortunate dicoveries shall have furnished the means of making it, and let us proceed with the application of known facts and principles.

A pleasing exhibition of the phenomena of electric attraction and repulsion, may be made in the following manner.

Take a glass tube, and after having rubbed it, let a small light feather fall from your fingers, at the distance of eight or nine inches from it.—The feather will be immediately attracted by the tube and stick very close to its surface for some seconds, after which it will be repelled, and if the tube be kept under it, the feather will continue floating in the air, at a considerable distance from the tube, without coming near it again, except it touch some conducting substance; and if you manage the tube dexterously, you may drive the feather through the air of the room at pleasure.

The cause of this phenomenon is obvious. The feather, at first, not being electrified, rushes to the excited tube. There it becomes electrified and is then repelled, and cannot approach the tube again, unless it first touch some conducting substance; because it cannot part with its electricity while floating in the air, and therefore cannot acquire a contrary electricity; consequently it must remain in a state incapable of being again attracted by the excited tube.

There is a remarkable circumstance attending this experiment, which is, that if the feather be kept at a distance from the tube by the force of electric repulsion it always presents the same part towards the tube. The reason of this phenomenon is, that the equilibrium of the fluid in the different parts of the feather being once disturbed cannot easily be restored; the feather being an electric, or at least a very bad conductor. When the feather has acquired a quantity of electricity from the tube it is plain that, by the action of the excited

tube, that superinduced electricity will, for the most part be forced to that side of the feather which, at first, happened to be farthest from the tube; hence that part will always afterwards be repelled the farthest.

This experiment may be agreeably varied in the following manner.—A person may hold an excited tube of glass, within a foot and a half of a stick of sealing-wax, or any other electric negatively electrified, held by another person; a feather let fall between these differently excited electrics will leap from one to the other alternately, and the two persons will seem to drive a shuttlecock by the force of electricity.

Another experiment calculated to shew the phenomena of electric attraction and repulsion is the *electric spider.*

Cut a piece of cork in the shape of a spider, and run a few short threads through it, to represent the legs; this done, suspend it by a silk thread from the ceiling of the room, or any other support, so that the spider may hang mid-way between the knob of a jar and the knob of a wire fastened to the table, or to the outside coating of the jar when not charged; let the place where the jar stands be marked; then charge and replace it. The spider will now begin to move from knob to knob, and continue this motion for a considerable time.

In this case, the knob of the jar is charged positively, and the spider, being in its natural state, is attracted by it; the knob then communicates to it some of its electricity, and the spider becoming possessed of the same electricity with the knob, is repelled by it, and immediately runs to the other knob, which communicates with the negative coating, or with the table, where it discharges its electricity and is again attracted by the

knob of the jar. This attraction and repulsion continue till the jar is discharged, when the spider finishes its motion and seemingly expires.

CHAP. IX.

Of the Leyden phial.

THIS consists of a glass phial, jar, or bottle, coated on the outside and inside with tin-foil, rendered adhesive by paste or gum water. About two inches of the glass at the top are left without any metallic covering, to prevent a communication between the outside and inside coatings, while the electricity is collecting.—The mouth of the phial or jar is furnished with a cork which receives a wire, ending in several ramifications which touch the inside coating. The upper end of this wire, which should extend a convenient distance above the mouth of the jar, is furnished with a metallic ball.

When the phial or jar is to be charged, it may be held in the hand or placed on an uninsulated table, with the knob of the wire touching the prime conductor. The inner surface of the glass now acquires the same electricity with the prime conductor, and the external one acquires a contrary electricity by means of its uninsulated coating.

When a phial similar to the one above described is highly charged, a spontaneous discharge will usually take place over the uncoated surface, and seldom through the glass. But if the uncoated surface be left larger than from two to three inches, the phial is more apt to crack and become useless, by the charge passing through the glass. There is not however an absolute

certainty that a jar which has once discharged itself over its surface will not, at another time, break by a discharge through the glass.

It was long disputed whether the discharge of the Leyden phial resided in the coating or in the electric. The following experiment clearly decides, that its residence is in the electric.

Upon an uninsulated plate of metal, lay a plate of glass considerably larger, so that there may be a rim of three or four inches projecting beyond the metal. Upon the glass lay another piece of metal, of the same size with the first, and so as precisely to cover it.

Let this instrument be charged, by connecting the upper metallic plate with the prime conductor. Then separate the metallic plates from the glass; and upon examination the glass will be found to possess the contrary electricities on its opposite sides; that side which during the electrization communicated with the prime conductor will have a like electricity with it, and the other the contrary.

Discharge the electricity of the metallic plates, and replace the whole apparatus in its former situation.—Take a discharging rod, formed by a piece of bent wire with a metallic ball at each end; touch the under plate and bring the other end of the wire near the upper plate. The consequence will be, that a strong and loud spark will pass between the upper plate and the discharging rod; the electricity of the glass will be discharged, and there will afterwards remain no signs of electricity, either in the glass, or the metallic plates.—Hence it appears that the electricity resides in the glass, and that the coatings, whether in a plane or spherical form, are of no other use than to convey the electric

fluid to the glass; to keep it equably distributed over the surface; and to form a communication between the different parts of the electrified glass, so that the discharge from them may be simultaneous.

When the discharge of a coated electric is made through the body of a living animal, it occasions a sudden motion, by contracting the muscles through which it passes, and gives a disagreeable sensation commonly called the *electric shock*.

CHAP. X.

The electrical battery—and experiments performed with it.

WHEN a greater degree of electric force is required than a single jar is capable of giving, the electrical battery is made use of as part of the apparatus, which takes its name from the formidable effects it produces. This battery consists of a number of coated jars, placed in such a manner that they may all be charged at the same time, and discharged in an instant; so that the whole force of electricity accumulated in them, may at once be exerted on the substance exposed to the shock.

In discharging electrical jars, the electricity goes in the greatest quantity through the best conductors, and by the shortest passage. Thus if a chain and a wire be made to communicate at the same time with the outer coating of a jar, and be both presented to the knob of that jar, the greater part of the charge will pass by the wire, and very little by the chain, because the latter is a worse conductor than the former, on account of its discontinuation at every link. When the discharge is

made by the chain only, sparks are seen at every link, which is a proof they are not in contact.

The force of an electric shock is not affected by the inflections of a conductor through which it passes, though it is sensibly weakened by its length. Hence, when the circuit or communication between the two sides of a Leyden phial is formed by one person applying his hands to the different sides, the shock is stronger than when it is formed by many persons joining hands. Yet a considerable shock was given by the Abbe Nollet, in the presence of the king of France, to one hundred and eighty men; who formed an electrical circuit.—They were all shocked in the same instant.

Doctor Watson and many other gentlemen of eminence in science, were at the pains of making experiments of the same kind. They found, by means of a wire insulated on baked wood, that the electric shock was transmitted instantaneously through the length of 12,276 feet.

Electricity transmitted in large quantities through living vegetables, destroys their vegetable life.

When transmitted, in the same form, through animals, it generally puts an end to animal life; though it is said that there are individuals who are not affected by it. Possibly the reason why some persons are not killed by very large electric shocks is, that their muscular system, or bodily organization, has something peculiar which protects them.

If an electrical circuit be made by means of imperfect conductors, as a slender piece of wood, a wet packthread, the discharge will be made silently.

If a small interruption of an electrical circuit be made in water, on making the discharge, a spark will

be seen in the water, which never fails to agitate it and sometimes breaks the vessel in which it is contained.

A strong shock from a battery, sent through a slender piece of metal, instantly makes it red hot. Usually it is melted in whole or in part. If the fusion be perfect it is reduced into globules of different magnitudes. In this experiment it is a little remarkable that the parts of the metal at which the fluid enters and issues, are most likely to be melted.

If the metal be enclosed between pieces of glass, the shock will force the melted metal into the substance of the glass, so that it cannot afterwards be removed, without scraping off part of the glass with it. In this experiment the glasses which enclose metal are commonly broken to pieces—It is seldom that they resist the force of a strong shock. If the glasses enclosing metal be pressed by a heavy weight, a small shock is often sufficient not only to raise the weight, but to break glasses of considerable thickness. When the pieces of glass are not broken, they are marked by the explosion with the most lively prismatic colours, which lie somtimes irregularly, and sometimes in their prismatic order.

Gun-powder may be fired by a charge from three square feet of coated glass. The powder is to be put into a quill, and then a wire is to be thrust into each end so as nearly to meet, and afterwards these wires are to be made a part of an electrical circuit—A less charge of electricity will be sufficient if iron filings be mixed with the gun-powder.

When a shoek somewhat less than is sufficient to melt a piece of metal is sent through a chain, a black dust, in the form of smoke, is seen to proceed from the

chain. This dust is probably some of the metal itself, partly calcined, and by the violence of the explosion forced from it. If the chain be laid upon a piece of paper, glass, or other electric, this, after the explosion, will be found stained with some indelible marks, and often shew evident signs of having been burnt.

What is more remarkable in considering the effects of electricity on metals is, that it often, in a considerable degree, revivifies their calces or oxyds. In making experiments of this kind, the metallic calx or oxyd is to be made a part of an electrical circuit, through which a strong shock is to be sent: when the calx or oxyd will be found in a measure restored to its metallic state: the electric shock having, as it appears, taken away from the oxyd a portion of its oxygen.

The electric shock when passed through the magnetic needle, sometimes destroys its magnetic virtue, and sometimes reverses its poles. It is affirmed that two ships sailing together on the same voyage, were led, from the effect of lightning on their needles, to steer exactly opposite courses, after the storm in which they were exposed to the lightning had subsided. When the charge of ten, eight, or even a less number of square feet of coated glass, is sent through a sewing needle, it will often give it polarity, so that it will traverse when laid upon water. In this experiment it is remarkable that if the needle be lying east and west, that end of it which communicated with the positive coating will point towards the north; but if the needle be struck while lying north and south, that end of it which lay towards the north, will, in any case, point north; and the needle will acquire a stronger virtue in this than in the former

case. But if the needle be placed perpendicular to the horizon, and the electric shock be given to either point of it, the lower extremity will afterwards point north.

The electric explosion taken upon the leaves of certain flowers changes their colour.

If the ball of a thermometer be placed in a strong current of electricity, the mercury or spirit will rise several degrees.

If a thin bottle be exhausted of air by means of an air pump, it will receive a considerable charge of electricity, by applying its bottom to an electrified prime conductor. In performing this experiment the bottle is to be held by the neck or near the mouth, and the electric matter will pass through the vacuum, and along the inner surface of the bottle, to the hand, from that end of it which is nearest to the prime conductor. The luminous appearance exhibited by this experiment is exceedingly beautiful in the dark, especially if the bottle be of any considerable length. It exactly resembles those lights which appear in the northern sky, and which are called streamers or the aurora-borealis. If one hand be applied to the part of the bottle which was before presented to the prime conductor, while the other remains at the neck, a shock will be felt, at which instant the natural state of the inner surface is restored by a flash, which is seen pervading the vacuum between the two hands.—The principle on which this experiment depends will be explained hereafter.

CHAP. XI.

A description of the electrophorus, and some of its phenomena accounted for.

THE electrophorus is a machine, consisting of two plates, usually of a circular form. At first the under plate was of glass covered with sealing wax; but there is little occasion to be particular, with regard, either to the substance of the lower plate, or to the electric with which it is covered; a metallic plate however is preferable to a wooden one, though the latter will answer very well. This plate must be covered with an electric: pure sulphur answers nearly as well as the dearer electrics gum-lac, sealing wax &c.

The upper plate is made of brass, or a piece of pasteboard covered with tin foil or silvered paper, which must be nearly of the same dimensions as the electric plate: this plate must be furnished with an electric handle, which, by means of a metallic or wooden socket is fastened to its centre.

This instrument was invented by Mr. Volta, an Italian philosopher. The manner of using it is as follows.

First, The under plate is excited, by rubbing its coated surface with a piece of new white flannel, or a fox's tail. A hard shoe brush, having the bristles a little greased, will also excite sulphur very well. When this plate is excited as much as possible, it is placed on a table with the electric side uppermost; the metallic plate is then laid on the excited electric; then the metallic plate is touched with the finger, or with any other conducting substance, which receives a spark from it; finally the metallic plate being held by the extremity

of its electric handle, is separated from the electric and after it is raised some distance, it is, on examination, found strongly electrified, with an electricity contrary to that of the electric, and will give a strong spark to a conductor brought near it. By placing the metallic plate upon the electric, touching it with the finger and separating them successively, a great number of sparks may be obtained, apparently of the same strength, and without exciting the electric again.—If these sparks be repeatedly given to the knob of a coated jar, it will become charged.

The action of these plates depends upon the principle already laid down (page 22,) that an excited electric has the power of inducing a contrary electricity in a body brought within its sphere of action. The metal plate therefore, when set upon the excited electric, acquires a contrary electricity, by giving its electric fluid to the hand or other conductor which touches it, when the electric is positively electrified; or by acquiring an additional quantity from the hand &c. when the electric is negatively electrified.

More fully to explain the principle here considered let the following easy experiment be made—

Electrify any insulated conductor *positively*. Then if an electrometer* of cork balls be held at some distance from it, the balls will diverge with *negative* electricity. This may be proved by bringing a piece of excited glass near them, as the balls will be attracted by it. But if you present to them a piece of excited sealing wax, they will immediately avoid it—that is, sup-

* This consists of two small balls of cork or pith, fastened to the ends of a thread or piece of silk. When it is to be used the thread or silk must be held by the middle so that the balls may hang close to one another.

posing the glass to be excited always positively, and the sealing wax always negatively.

Again. Insulate, in a horizontal position, a metallic rod with blunt terminations, and about two feet long. We shall designate the ends of this rod by A and B. Let a cork ball electrometer be affixed to the extremity A; then bring an excited glass tube within eight or ten inches of the other end B—the balls will immediately diverge with positive electricity. If the tube be removed the balls will immediately collapse, and no electricity will remain in them, or in the rod—But if, while the tube is near one end B of the rod, and the balls diverge with positive electricity, the other end A be touched with a finger or other uninsulated conductor, the cork balls will immediately come together, as if the rod were in its natural state: but if, in this state of things, the exeited tube be removed, the balls will again diverge, but with negative electricity, shewing that the whole rod AB is now under-charged.

This last experiment is thus explained—When the rod is in its natural state, the electric fluid proper to it is equably distributed throughout the rod; but when the excited glass tube is brought near one of its ends as B, the fluid belonging to that end will be driven towards A; which extremity becomes over-charged, and the other extremity B under-charged; yet the rod has no more electricity now than it had before, and when the tube is removed beyond the sphere of its action, the redundant fluid of A returns to its former place B, and the equilibrium is restored. But if the extremity A be touched, while it is over-charged, by a conductor, this will carry off its superfluous fluid, and leave the extremity A in its natural state, the extremi-

ty B being at the same time negatively electrified : and when the tube is removed, part of the fluid naturally belonging to A goes towards B, and the whole rod remains under-charged.

CHAP. XII.

Of electrometers.

WE have already seen that it is a general law of electricity, that similar electricities repel, and that dissimilar electricities attract each other—On this law all electrometers are constructed. In fact the cork balls, which have been mentioned are electrometers, and exhibit at once the most important phenomena for the explanation or ascertaining of which the instruments which bear this name are constructed. Still it is of use to see the application which may be made of this general principle. It is applied to ascertain the quantity of the electric fluid collected either in a prime conductor or a coated jar; and also the state of the atmosphere in regard to electricity, and the character of that electricity at any particular time and place.

The instruments by which these purposes are effected we shall now shortly describe.

To ascertain the quantity of electricity in a prime conductor or jar, an electrometer the most easily constructed and of the most general use has been invented by Mr. Henley—called the quadrant electrometer.—Of this we have given a representation in the frontispiece, (letter X.)

It consists of a perpendicular stem formed at the top like a ball, and at the lower end with a screw, by which

it is fastened to the prime conductor. A graduated semicircle of ivory, horn or stiff paper, is fixed near the uppermost end of the stem. A moveable index, made of a slender piece of hickory, extends from the centre of the graduated semicircle a little distance beyond its circumference, having a small ball of cork or pith at its lower extremity.

When the conductor or jar is not electrified, the index is parallel to the stem, but when it is electrified the index recedes more or less, according to the degree of the electrization, which is marked on the graduated circle.

A simple atmospheric electrometer was constructed by Mr. Cavallo in the following manner.—

To the end of a common fishing rod, he affixed a slender glass tube covered with sealing wax, and having a cork at its end, from which two cork or pith balls were suspended by hempen strings. From the other end of the rod proceeded a flaxen or hempen twine a little longer than the whole rod and tube, with a pin attached to it, which was stuck into the cork at the extremity of the glass tube, for the purpose of taking off the insulation. The twine, to prevent its falling when the pin was pulled out of the cork, was attached to the rod, by a small string, running from it and meeting the rod at a little distance from the glass tube.

To use this instrument, let the pin be pushed into the cork. Then, holding the rod by the extremity farthest from the cork balls, project it out, from a window in the upper part of the house, into the air, raising the end of the rod to which the balls are appended, so as to make an angle of 50° or 60°, with the horizon.—

After having kept it in this situation a few seconds, by pulling the twine, detach the pin from the cork—This leaves the electrometer insulated, and electrified with an electricity contrary to that of the atmosphere. Now draw the instrument into the room and you may examine the quality of the electricity, by applying the knob of a phial positively charged to one of the balls; if the ball is attracted by the knob it is negatively electrified—if repelled, positively electrified.

The satisfaction arising from these experiments is sometimes abated, from the circumstance that the quantity of electricity obtained in this way, is so small that its quality cannot be ascertained. To remedy this inconvenience Cavallo and Nicholson, have invented machines which they denominate *doublers* or *multipliers* of electricity. But the structure of these machines is complex and delicate, and the explanation of them is long, and not easily understood without the aid of plates. Our epitome therefore does not admit of inserting them. Those who may choose to pursue the subject we refer to the writers above mentioned.

To prevent the inconvenience arising from wind and rain in the use of the atmospheric electrometer, the following device has been used by Mr. Cavallo.—Take a glass vessel open at top and bottom—cement it at bottom to a convenient piece of wood—let the upper part be tapering like the neck of a phial, and cement into it a glass tube, extending a little above and a little below the neck of the larger vessel. Cover the tube with sealing wax, both within and without the neck of the vessel, so as to give it the appearance of one body. Into this tube cement a brass wire extending a very

little below the bottom of the tube, and flattened at the lower end so as to be perforated with two small holes. Through these holes insert two flaxen threads, or two very fine silver wires, with small balls of cork or pith at the end of them, and touching each other :—if wires are used they should be suspended by small rings at the top, that they may act more easily. Let the top of the brass wire screw into a brass cover on the top of the whole vessel, which cover will not only secure the vessel against rain, but serve as a conductor to a very slightly electrified atmosphere—conveying the fluid, first to the wire, and by means of that to the balls, which will exhibit, within the vessel, the state of electricity collected from the atmosphere. There should be two narrow slips of tin foil stuck to the inside of the glass vessel, and communicating with the wooden bottom, which will serve to carry off that electricity which, when the corks touch the glass is communicated to it, and which, if accumulated, would disturb the free motion of the corks.

An useful alteration of this electrometer was made by Mr. Bennet. It consists of slips of gold leaf or silver leaf, instead of the corks suspended by threads or wires. These slips of leaf are to be suspended from the cover of a cylindrical vessel, and hanging within it. The slips of leaf are to be about two and an half inches long. This electrometer is the most sensible instrument of the kind, manifesting in an unequivocal manner very small quantities of electricity. But this instrument is not as portable and easily managed as the other.—If very fine threads, stiffened with glue, be used without any balls, they will be found nearly as sensible as the gold leaf.

CHAP. XIII.

The identity of electricity with lightning.

THE identity of the electric matter with lightning is a discovery, which has been of more use than any other in electricity.

That the effects of this fluid bore a great resemblance to those of lightning, had been several times remarked by philosophers and especially by the Abbe Nollet; but that they should be found to be effects of the same cause, and that the phenomena of electricity could be imitated by lightning, or those of lightning by electricity, was not suspected, till our countryman Dr. Franklin made the assertion in 1750, and afterwards demonstrated its truth by undeniable experiment in 1752.

This discovery is almost the only one in the whole science which has not been the result of accident.

The Doctor had for a long time observed the effects of pointed bodies in drawing off the electric matter more powerfully than could be done by others.—Improving upon this, he supposed that pointed iron rods, raised to a considerable height in the air, when the atmosphere was loaded with lightning, might "draw off the matter of the thunder-bolt, without noise or danger." As he was waiting for the erection of a spire in Philadelphia, that he might have an opportunity of ascertaining the correctness of his hypothesis, it occurred to him, that, by means of a common kite, he could have a readier access to the higher regions of the atmosphere than in any other way. Preparing therefore a large silk handkerchief, and two cross sticks upon

which he might easily extend it, he took the opportunity of the first approaching thunder-storm to walk into a field, where there was a shed convenient for his purpose; but, dreading the ridicule which too commonly attends unsuccessful attempts in science, he communicated his design to no one but his son, who assisted him in preparing and raising the kite.

A considerable time elapsed before there was any appearance of success: one very considerable cloud had passed over the kite without any effect; when, just as he was beginning to despair, he observed some loose threads of the hempen string to stand erect, and avoid one another just as if they had been suspended from the prime conductor of an electrical machine. On this he presented his knuckle to a key which was fastened to the string, and received a spark. Others succeeded even before the string was wet; but when the rain began to fall he collected the electrical fire very copiously.

He afterwards had an insulated iron rod, to draw lightning into his house, and performed almost every experiment with real lightning, that he had before made with electricity collected by a machine. Thus a new field was opened for the philosophy of electricity.

CHAP. XIV.

Of the structure and use of the electrical kite.

IN the structure of an electrical kite, the circumstances to be principally attended to are those near, and on the ground. Silk being a non-conductor, the end of the string which is held in the hand is to be of that substance—a silk handkerchief tied to the hempen

twine of the kite will answer very well. An iron key is to be tied on the hempen string, an inch or two above its junction with the silk, and from this key, when the kite is electrified, the sparks are to be received into a Leyden phial, to be used in the same manner as if it had been charged from the electrical machine. As curiosity may prompt many to repeat the experiments made with this kite, and as no experiments with atmospheric electricity can be made without some danger,* we shall give the substance of Mr. Cavallo's

* Mr. Richman professor at Petersburg was killed on the 6th of August, 1753, by the lightning which he had drawn into his room, for the purpose of making experiments. The circumstances of this interesting and instructive occurrence were the following.

He had provided himself with an instrument for measuring the quantity of electricity communicated to his apparatus, and as he stood with his head inclined towards it, Mr. Solokow, an engraver, who was near him, observed a globe of blue fire as large as his fist, jump from the instrument, which was about a foot distant, to Mr. Richman's head. The professor was instantly dead, and Mr. Solokow much hurt. The latter however could not give any particular account of the way in which he was affected; for at the time when he was struck, there arose a sort of steam or vapour, which entirely benumbed him, and made him sink to the floor; he did not even remember to have heard the clap of thunder, which was very loud.—The globe of fire was attended with an explosion like that of a pistol; the instrument for measuring the electricity (called by the professor the electrical gnomon) was broken to pieces, and the fragments scattered about the room. Upon examining the effects of the lightning in the chamber, the door-case was split half through, and the door torn off the hinges, and thrown into the room.

They opened a vein in the body twice, but no blood followed; after which they endeavoured to recover life by violent friction, but in vain: upon turning the corpse with the face downwards, during the friction, a quantity of blood ran from the mouth. There appeared a red spot upon the forehead, from which spirted a few drops of blood from the pores, without wounding the skin; the shoe of the left foot was torn open, and upon uncovering the part, a blue mark was found; from which it was concluded, that the electric matter having entered at the head, made its way out again at the foot. Upon the body, particularly on the left side, were several red and blue spots, resembling leather shrunk by being burnt. Many more

directions (the best we are acquainted with) relative to the forming and using of this instrument.—He observes that the whole power of the machine lies in the string: and that in other respects a common school boy's kite, will answer the purpose as well as any other. The string is made by twisting two threads of twine with one of brass wire or copper, such as is commonly used for trimmings. When a kite constructed in this manner was raised, the string always gave signs of electricity except once, when the weather was warm, and the wind so weak that the kite could not be kept up for a few minutes; afterwards, however, when the wind increased, he obtained as usual a considerable quantity of electricity.

Concerning the management of this kite he gives the following directions.—

In raising the kite when the weather is very cloudy and rainy, at which time there is much danger of meeting a great quantity of electricity, I usually hang upon the string a chain with one extremity touching the ground; and sometimes I use another caution besides, which is, to stand upon an insulated stool; in which situation, I think that if any quantity of electricity, suddenly discharged by the clouds, strikes the kite, it cannot much affect my person. Although I have raised my electrical kite a hundred times without any caution

also became visible over the whole body, and especially over the back.—That on the forehead changed to a brownish red, but the hair of the head was not singed.

In the place where the shoe was unripped, the stocking was entire, as was the coat every where; the waistcoat being only singed at the fore flap where it joined the hinder; but on Mr. Solokow's coat there appeared long narrow stripes, as if the nap had been burnt off by red hot wires. These could not be accounted for.

whatever, I have very seldom received a few exceedingly slight shocks in my arms. In time of a thunder-storm, if the kite has not been raised before, I would not advise a person to attempt it while the stormy clouds are over head, the danger at such time being very great, even when every caution is used. At that time the electricity of the clouds may be observed by means of a cork ball electrometer, placed in an open situation.

But Mr. Cavallo with all his caution could not avoid danger in making experiments on atmospheric electricity, as appears from the following account of his observations on the 13th of October 1773. "After having rained a great deal in the morning and the night before, the weather became a little clear in the afternoon, the clouds appearing separated and pretty well defined; the wind was west and pretty strong; the atmosphere was in a temperate degree of heat. In these circumstances, at three o'clock P. M. I raised my electrical kite, with 360 feet of string. After the end of the string was insulated, and a leather ball coated with tin foil, hung to it, I tried the power and quality of the electricity, which appeared to be positive and pretty strong; in a short time a small cloud passing over, the electricity increased a little; but the cloud being gone it returned pretty soon to its former degree.

The string of the kite was now fastened by a silk string to a post in the yard of the house; I was repeatedly charging two phials, and giving shocks with them: while I was so doing, the electricity, which was still positive, began to decrease, and in two or three minutes it became so weak, that it could hardly be perceived, with a very sensible cork ball electrometer.—

Observing at the same time that a large black cloud approaching the zenith, (which no doubt caused the decrease of electricity) indicated rain, I introduced the end of the string through the window on the first floor, where I fastened it by the silk to an old chair.—The quadrant electrometer was set upon the same window, and was, by means of a wire, connected to the string of the kite. Being now three quarters of an hour after three, the electricity was actually imperceptible, however in about three minutes it returned, but now upon examination, it was found to be negative, which was evidently occasioned by the approach of the cloud, which by this time had reached the zenith of the kite; the rain also began to fall in large drops. The cloud came farther on, the rain increased and the electricity keeping pace with it, the electrometer soon arrived at 15°. Seeing now that the electricity was strong, I began again to charge the phials and to give shocks with them; but the phials had not been charged more than three or four times, before I perceived that the index of the electrometer was arrived at 35°, and was still rising. The shocks now being very smart, I desisted from charging the phials, and considering the rapid advance of the electricity, thought to take off the insulation of the string, that if it should farther increase it might be conducted silently to the earth, without occasioning any bad accident.

To effect this, as I had no proper apparatus near me, I thought to remove the silk string, and to fasten the twine itself to the chair. I disengaged the wire which connected the electrometer with the string; untied it from the silk, and fastened it to the chair: but while I was effecting this, which took up less than half a minute,

I received twelve or fifteen very strong shocks, which I felt all along my arms, in my breast, and legs, shaking me in such a manner that I had hardly power to effect my purpose, or to warn the people of the room to keep their distance. As soon as I took my hands from the string, the electricity (in consequence of the chair being a bad conductor) began to snap between the string and the window shutter, which was the nearest conductor. The cloud was now just over the kite; it was black, well defined, and nearly of a circular form, its diameter appearing to be about 40°; the rain was copious but not remarkably heavy.

As the cloud was going off, I went near the string, and finding the electricity weak, but still negative, I insulated it again, thinking to keep it up some time longer; but observing that a larger and denser cloud was approaching, I resolved to pull the kite in; accordingly a gentleman, who was near me, began pulling it while I was winding up the string, he told me he had received two or three slight shocks in his arms, and if he should feel one more, he would let the string go; upon which, I pulled the kite in as fast as I could myself, without any further observation, being ten minutes after four o'clock.

N. B. There was no thunder or lightning perceived that day, nor for some days before, nor afterwards."

The general laws which Mr. Cavallo deduced from a variety of experiments made by means of electrical kites, are the following:

1st. The air appears to be electrified at all times; its electricity is always positive and much stronger in frosty than in warm weather; it is by no means less in the night than in the day time.

2d. The presence of thé clouds generally lessens the electricity of the kite, sometimes it has no effect upon it, and it sometimes, though rarely, increases it a little. To this the above mentioned instance is a remarkable exception.

3d. When it rains, the electricity of the kite is generally negative, and very seldom positive.

4th. The aurora-borealis seems not to affect the electricity of the kite.

5th. The electrical spark taken from the string of the kite, or from an insulated conductor connected with it, especially when it does not rain, is seldom longer than the quarter of an inch; but it is exceedingly pungent. When the index of the electrometer is not higher than 20° the person who takes the spark will feel it in his legs; it appearing more like the discharge of an electrical jar, than the spark taken from the prime conductor of an electrical machine.

6th. The electricity of the kite is generally stronger or weaker, according as the string is longer or shorter; but it does not keep any exact proportion to it; the electricity, for instance, brought down from a string of an hundred yards, may raise the index of an electrometer to 20°, when with double the length of string, the index of an electrometer will not go higher than 25°.

7th. When the weather is damp, and the electricity pretty strong, the index of an electrometer, after taking a spark from the string, or being presented to the knob of a coated phial, rises surprisingly quick to its former place; but in dry and warm weather it rises exceedingly slowly.

CHAP. XV.

The structure and use of lightning rods.

SINCE the discovery of the identity of lightning and the electric matter, long rods of iron, or other metals, have been made use of, with a view to protect buildings from the effects of lightning. This is the most practical and important part of our whole subject, and deserves to be treated with the utmost attention. Iron and copper are the metals which, on account of their conducting power, their cheapness, and the quantity required for a lightning rod, are principally used. Copper is preferable to iron. Care should be taken that the rod be not less than half an inch in diameter. It is best to have it, if possible, of one continued piece. If this be not practicable, the pieces should be screwed into each other; or at least so constructed that the rust will not separate the perfect metal of one piece from that of another; because metallic rust is almost a non-conductor of electricity. The rod should be fastened to the house by wooden cramps or staples, rather than by those of metals of any kind; because wood is neither so good a conductor of electricity, nor so likely to promote the rust of the metal which it touches. The rod should be raised above the top of the building or chimney to which it is attached, at least five or six feet. The point or points should be made very sharp, and for a few inches should taper off in the form of a pyramid, having all the corners or edges sharp. It is not of much importance whether there be, or be not, more points than one. If the means afterwards to be mentioned be not used to preserve the points from rust, it may

be of use to gild them; and the gilding should extend downwards a foot or more. It is better to paint the point of a rod, than to leave it wholly unprotected against rust. The lower end of the rod should be driven or sunk at least five or six feet into the ground, and in a direction from the building. If it can be connected with the water of a spring, a well, or a cistern, it will be so much the better. At powder-mills, arsenals, and all depots of inflammable materials, it is better to attach the rod to a post, raised for the purpose, a foot or two from the building, than to the building itself. If the building be large, there should be a rod at each end; and it is an additional security, if these rods be connected by a piece of metal, running from the one to the other, on the roof of the house. If there be but one rod, it should, in this country, be put on the western end of the house; because thunder-storms oftenest arise from that quarter. If the position of the house affords but little choice in this respect, the rod should be placed either on the kitchen chimney, or as near to it as possible; because smoke and heat are conductors, and in the summer, smoke and heat seldom ascend from any other chimney than that of the kitchen. When there is a copper spout to a house, the rod, if convenient, may be connected with it as a part of the conductor. In this case however, care should be taken to make the connexion complete, both at top and bottom. Large barns and barracks, have even more need of a rod to preserve them from lightning than a dwelling house, because the vapour which ascends from them when filled with vegetable substances, imperfectly dried, is a powerful conductor.

Ships, and all vessels which have high masts, have as much need of conductors as houses on the land. Copper conductors are in every view the best for ships, as they will not contract rust from sea water. A conductor, of this metal, should be attached to the highest mast of the vessel, and extend three or four feet above its top. It should be inserted into the side of the mast, so as to leave the surface smooth, be carried across the deck and over the side of the ship to the keel; so that it may terminate where the lower extremity may be always under the water. Chains are often used as conductors to ships, but they are far inferior to a piece of metal, whose parts are not separated.

In the above directions it has been our aim to show in what manner structures may be best and most effectually protected against danger from lightning, and whenever it is practicable the best means ought certainly to be used. But it is to be remembered that where means the most effectual cannot be applied, those of an inferior kind are not to be neglected. A small rod, however pointed or fastened to a house, is unspeakably better than none, and a chain should always be used in a ship, if a rod cannot be obtained. In ninety nine cases out of a hundred, any metallic conductor, reaching from the top to the bottom of a structure, will preserve it from destruction by lightning, and save the lives or property of the inhabitants, when the whole might otherwise have been destroyed.

The points of rods have often been found melted by lightning, and both they and the lower extremities are often injured by rust. For an effectual method of preventing both these inconveniencies, the public are indebted to Robert Patterson Esq. professor of mathema-

tics in the University of Pennsylvania, and director of the Mint of the United States.—His memoir on the subject is as follows:—

"From the instances which now and then occur of houses being struck with lightning, that are furnished with metallic conductors, and the frequent instances of these conductors having their tops melted off by a stroke of lightning, it appears that this admirable contrivance for guarding houses against the dangerous effects of lightning is, in some degree, still imperfect. Some improvement seems yet to be wanting at both extremities of the rod—at the upper extremity, to secure it against the accident of being melted, which renders it afterwards unfit to answer its original intention, viz. drawing off the electricity, or lightning, from the passing cloud, in a silent imperceptible manner, for it is only *pointed* conductors that possess this property—and at the lower extremity, to afford a more ready passage for the fluid into the surrounding earth.

The first of these intentions, would I am persuaded, be effectually answered by inserting in the top of the rod a piece of *black lead*, of about two inches long, taken out of a good pencil, and terminating in a fine point, projecting but a very little above its metallic socket; so that if the black lead point should happen to be broken off by any accident, of which however I think there can be but little danger, still the point of the rod would be left sharp enough to answer the purpose of a metallic conductor.

This substance is well known to be infusible, by the greatest heat, and hence its use in making crucibles; nor is it evaporable as remarked by Cronstedt, in his mineralogy, Sect. 231, except in a slow calcining heat,

to which it could never be exposed at the top of a lightning rod.

At the same time its power as a conductor of electricity is perhaps equal, or but little inferior, to that of any of the metals. A line drawn on a piece of paper by a black lead pencil, will as I have often experienced, conduct an electric explosion seemingly as well as a similar line of gilding would do, and that without ever loosing its conducting power, which is not the case with gilding.

The second intention is, to facilitate the escape of the electric fluid from the lower part of the rod into the surrounding earth.

It is in many cases impracticable, from the interruption of rocks or other obstacles, to sink the rod so deep as to reach moist earth, or any other substance which is a tolerably good conductor of electricity. Nor, even if this were practicable, would it, I presume, be alone sufficient to answer the desired intention. Iron, buried in the earth, and especially in moist earth, will presently contract a coat of rust, which will continually increase till the whole is converted into rust, but rust of iron, and indeed the calx of all metals is a non-conductor, or at most but a very imperfect conductor of the electric fluid. Hence it is easy to see, that in a few years after a lightning rod has been erected, that part of it which is under ground will contribute little or nothing towards the safety of the building. Besides, the surface of this part of the rod is too small to afford an easy and copious discharge of the electric fluid into the surrounding earth, when this is but an imperfect conductor.

As a remedy for these defects I would propose, that the parts of the rod under ground be made of tin, or copper, which are far less liable to corrosion or rust, by lying under ground than iron—Or, which perhaps would answer the purpose better, let this end of the rod, of whatever metal it be made, be coated over with a thick crust of black lead, previously formed into the consistence of paste, by being pulverised and mixed with sulphur (as in the manufactory of the ordinary kind of black lead pencils) and then applied to the rod while hot. By this means, the lower part of the rod would, I apprehend, retain its conducting power for ages, without any diminution.

In order to increase the surface of the lower part of the conductor, let a hole or pit, of sufficient extent, be dug as deep as convenient; and into this pit let there be put a quantity of *charcoal*, round the lower extremity of the rod. Charcoal possesses two properties, which, in a peculiar manner, fit it for answering the purpose here in view.—(1st,) It is a very good conductor of electricity and, (2d.) It will undergo little or no change of property by lying ever so long in the earth. Thus might the surface of that part of the conductor, in contact with the earth, be increased, with little trouble or expense to any extent at pleasure; a circumstance which every one acquainted with electrical experiments, must acknowledge to be of great importance to the end here proposed."

The following experiments with a thunder-house, shew the utility of lightning rods, and ascertain what termination of the rod best answers the end proposed.

To shew the effect of lightning on a house not furnished with a conductor, or when the conductor is discontinued.

Provide yourself with the model of a house made of tin, four inches in breadth, six long, and about five in height. Let there be a chimney placed in the roof equidistant from both ends, and let a glass tube pass through it, the upper extremity of which must reach a little above the chimney, and the lower one come within an inch of the floor of the house.—Let a small wire pass through the bore of the glass tube, the upper end of which must extend a small distance above the orifice of the tube, having its extremity, which must be pointed, furnished with a screw, on which a metallic ball is to be fastened. The other end must likewise have a ball fixed upon it.—The instrument being thus prepared, fill the house with cotton, and sprinkle a little powdered rosin on that part of it, which is immediately between the lower knob of the wire, and the floor of the house. Then connect the lower part of the instrument with the outside coating of a pretty large jar.—From the prime conductor, in order to represent the clouds, suspend a small scale beam, having two balls of metal or wood coated with tin foil, in the place of the scale dishes, nicely balanced. The knob of the jar being connected with the prime conductor; bring the ball on the wire extending through the glass tube, under one of the balls representing a cloud.—Now charge the jar. The cloud will be attracted by the ball on the wire—the electricity of the cloud will be discharged—and if the experiment succeeds, the contents of the house will be set on fire.

The effects of lightning, when a house is furnished with a pointed conductor.

Repeat the above experiment with this variation: unscrew the ball from the upper extremity of the wire of the house, so that it may remain pointed. Place the house under the cloud as in the former experiment.—You will now find it impossible to charge the jar: or if you charge the jar before the house is placed under the cloud; the cloud, instead of being attracted by it, will be repelled, and the jar will be discharged without any explosion, and without firing the cotton.

These two experiments evince that *pointed* conductors are more proper to secure houses from the effects of lightning that those terminating with a ball or knob, and that if the pointed conductors fairly act on the cloud the security is complete.

CHAP. XVI.

Of animal electricity.

THE electric power, observed by the ancients only in amber, and perhaps the tourmaline, was in process of time found to be in glass, rosin, silk, and several other substances. By degrees it was discovered, that very strong signs of electricity were exhibited by a number of animals. The experiment of producing sparks of electrical fire, by rubbing the back of a cat in frosty weather, proved that electricity might exist in a very active state in the bodies of animals, without injuring their functions. From animals of an inferior kind a transition was made to the human species. Some

people were observed to have a remarkably bright lustre of their eyes, others were found to be so strongly electrified naturally, that a very sensible electrometer was perceptibly affected, when brought near them.—Others, it is affirmed, were found so sensible to the presence of electricity, as to be affected by a flash of lightning, though so distant that the thunder could not be heard. But what principally claims our attention in regard to this part of our subject is, that there are unquestionably certain animals which can at pleasure give an electric shock, of sufficient force to kill other small animals, and that in fact they often do it. We shall describe only three of the most remarkable of these electric animals—the Gymnotus electricus, the Torpedo, and the Silurus electricus.

The Gymnotus is a genus of fishes, belonging to the order of apodes. They have two tentacula at the upper lip; the eyes are covered with the common skin.—There are five rays in the membrane of the gills; the body is compressed, and carinated on the belly with a fin. There are five species; the most remarkable is the *electricus*, commonly called the *electric eel.* This species is peculiar to the Surrinam river, and they inhabit the most rocky parts of it, at a considerable distance from the sea.—The most accurate description of this fish, is in the Philosophical Transactions, for 1775, where Alexander Garden M. D. gives an account of three of them brought to Charleston in South Carolina. The largest was about three feet eight inches long, and from ten to fourteen inches in circumference, about the thickest part of the body. The head was large, broad, flat, and smooth, impressed here and there with holes, as if perforated with a blunt needle, especially

towards the sides, where they are more regular. There are two nostrils on each side; one is large, tubular, and elevated above the surfaee; the other small and level with the skin. The mouth is large, but the jaws have no teeth, so that the animal lives by suetion, or by swallowing its food entire.

The eyes are small, flat, and of a blueish colour, plaeed a little behind the nostrils. The whole body from a few inehes below the head, was distinguished into four longitudinal parts, clearly divided from each other by lines. The carina begins a few inches below the head, and widening as it proceeds, reaehes as far as the tail, where it is thinnest. The situation of the *anus* is very remarkable, being an ineh more forward than the peetoral fins. Aeross the body, there are a number of small bands, annular divisions, or rather rugæ of the skin; by means of whieh the fish seems to partake of the vermieular nature, having the power of lengthening and shortening its body like a worm, and by means of whieh it can swim baekwards as well as forwards.—For an anatomieal deseription of this fish, see the appendix to the 2d. vol. of Mr. Cavallo's "Complete treatise" page 303.

The Gymnotus has the astonishing property of giving the eleetrie shoek to any person or number of persons, either by the immediate toueh of the hand or by the mediation of any metallie eonduetor. The shoek is interrupted by the intervention of a non-conducting substanee. If the animal be touehed only with one hand, a kind of tremor is felt in that hand only. The power of giving shoeks depends entirely on the will of the animal.

As nature is ever provident for her creatures, both with regard to their preservation and support, she has endowed the Gymnotus with a peculiar instinctive faculty, so that if it be pursued by an enemy, it never fails to communicate a shock, in consequence of which it eventually makes its escape. In obtaining food it likewise makes use of its electrical property by which it kills small fish, and afterwards devours them.

But the most remarkable instinct of this fish is, that when any substance approaches it, it is sensible whether it be a conductor or non-conductor. In order to exhibit this wonderful phenomenon, a variety of methods were contrived, the easiest and most satisfactory one was the following. The extremities of two wires were dipped into the water of the vessel, in which the animal was kept, after which they were extended to a considerable distance, where they terminated in two separate glasses full of water. These wires being supported by silk at some distance from each other, the circuit was, of course, incomplete. In these circumstances if a person completed the circuit, by placing one hand in one of the glasses and the other in the other, the fish which never went purposely towards the wires, while the circuit was interrupted, would now go immediately towards them and give the shock, and this though the completion of the circuit was made out of his sight.

The next electrical fish we are to mention is the Torpedo; a genus of fishes belonging to the order of Chondropterygia; the species of this genus are remarkable and numerous; but we must content ourselves with the sixth species, called the *electrical ray*, or *cramp fish*, or Torpedo. The head and body, which are indistinct,

are nearly round, the ventral fins form on each side the quarter of a circle, the two dorsal fins are placed on a trunk of the tail, which is round, the caudal fin is broad and abrupt. The eyes are small, and placed near each other; behind each is a round spiracle with six small cutaneous rags on their inner circumference.—The mouth is small, and the teeth are minute and spicular.

These fish have been taken in Torbay, off Pembroke, near Waterford in Ireland, and many other parts of Europe, with a trawl, and sometimes with a bait; they commonly lie about forty fathoms deep. The food of the Torpedo is fish.—For an anatomical description we refer the curious reader to one given by Mr. Hunter, in the Philosophical Transactions, vol. 63.

The electrical properties of this fish are remarkable; for a long time they were considered as fabulous; but the fact having been ascertained beyond the possibility of doubt, it was endeavoured to be accounted for, by a variety of ingenious though unsatisfactory arguments. But when the phenomena of electricity began to be better understood, considerable light was thrown upon the subject; and Mr. Walsh at last, not only explained the phenomena which generally attend it, on the known principles of electricity, but actually contrived an artificial fish, by which a shock very similar to that of the natural one can be given.

The electrical power of the Torpedo is conducted by the same substances as conduct common electric matter, and is interrupted also by the same non-conductors: but its shock will not pass over the least interception of the circuit, not even if a chain be used.

This singular fact was also imitated by Mr. Walsh with his artificial Torpedo.

It has not been in our power to obtain a particular account of this artificial Torpedo of Mr. Walsh.—But we know that one may be formed in the following manner.

Let a number of small thin laminæ of talc, commonly called isinglass, or thin sash glass, coated in the usual way, be joined together in the same manner as in the battery. Let these be placed in the body of an artificial fish resembling the Torpedo.—Let them then be charged, and on being touched, the same phenomena which accompany the real Torpedo will ensue; except that the shock of this will not be impeded by a small interruption in the circuit. Similar effects may also be produced, by means of a large battery weakly charged and furnished with Lane's electrometer.

The third and last fish that we shall mention, is the Silurus or Silurus electricus, a genus in Ichthyology belonging to the order of Pisces Abdominales.—The body of this is long, smooth, and without scales, being rather large and flattened towards the lower part. The eyes are of the middle size and covered by the skin which envelopes all the head. Each of the jaws is furnished with a great number of small teeth. About the mouth it has six filamentous appendices, two from the upper, and four from the under lip. The colour of the body is greyish, with a few dark spots towards the tail.

With regard to its electrical properties very little is known, enough however to entitle it to the name of electricus.

CHAP. XVII.

The influence of electricity on vegetables.

WITH regard to this part of our subject there has been considerable controversy between philosophers, some of them asserting that electricity is unfavourable, and others that it is advantageous to vegetation. It was asserted by the Abbè Bertholon, in his book entitled Electricitè des meteores, that plants situated near a metallic conductor increased considerably in consequence of their situation. And, on the other hand, Giardini says that plants growing near such conductors are generally unhealthy, and produce very little fruit, but upon removing the conductor the plants become luxuriant and fruitful.

The Abbè Bertholon in endeavouring to establish his opinion, constructed what he called an *electro vegetometer* by means of which the eletricity of the atmosphere may be collected in abundance. "This apparatus (says he) having been raised with care in the midst of a garden, the happiest effects were perceived, viz. different plants, herbs and fruits, in greater forwardness than usual, more multiplied and of better quality." These facts are analogous to an observation that I have often made, viz. that plants grow best, and are more vigorous near thunder rods, where their situation favours their developement. They likewise serve to explain why vegetation is so vigorous in lofty forests, and where the trees raise their heads far from the surface of the earth, so that they seek as it were the electric fluid at a far greater height than plants less elevated: while the sharp extremity of their leaves, boughs and branches

serve as so may points granted them, by the munificent hand of nature, to draw down from the atmosphere that electric fluid which is so powerful an agent in forwarding vegetation, and in promoting the different functions of plants.—Such are the theory and experiments of the Abbè, but Doctor Ingenhaus, in two letters to Mr. Molitor, published in the *journal de physique* for 1786—88 has shewn the fallacy of the theory, by exposing the insufficiency of the experiments upon which it was established.

We shall translate a few passages from the Doctor's letter, which will shew us his opinion and the result of his experiments.

I have frequently made experiments of this kind by exposing plants to a weak degree of electricity, and at other times to a considerable quantity, without ever being able to observe that plants under its influence prospered more than those which were not electrified at all. It even appeared to me more than once, that those which had been electrified were a little less thrifty than those which were not electrified.

In another place he says, Not being content with these experiments, I have made others infinitely more conclusive, by strewing seeds of mustard and cresses, over the largest plates of delf that I could procure, covering them with brown paper, and sprinkling them continually with a sufficiency of water. Each of these plates was covered with more than a thousand seeds; I kept them electrified night and day, according to the method which Mr. Schewankhard directed, in a letter quoted by Mr. Elermann, but which I shall not repeat in this place, lest I should swell this memoir: the vegetation of these little shrubberies was always more or

less precarious, in proportion to the greater or less quantity of light that they received; the electricity really contributing nothing to advance the growth: thus the controversy stands, we leave the reader to form his own opinion.

That some plants are more affected than others by electricity is an unquestionable fact. It is however not true as some have affirmed, that the contractions of the mimosa or sensitive plant, are attributable to this cause. The plant is equally affected when touched either by a conductor or an electric.

CHAP. XVIII.

Medical electricity.

ELECTRICITY has one advantage over other medical applications, in as much as it may be applied to the healthy, as well as the diseased part of the body, without proving prejudicial, and because it requires rather a nice application, than a perfect knowledge of the complaint. In a number of cases it has unquestionably proved salutary.

When electricity was first used in removing bodily complaints, it was done only by means of the Leyden phial pretty highly charged; but this mode of administering it, was strenuously opposed by Mr. Lovet, who was a celebrated electrical practitioner, and in an essay called *Subtil medium proved*, asserts that electricity should be used in small sparks, by which mode of treatment he affirms he scarcely ever failed curing or at least relieving his patients.

The apparatus for medical electricity in addition to the machine described in chapter IV, is an *insulating stool.* This stool is made in the common way, only that the feet must be of glass, the upper or wooden part, should be about three feet square, so that a chair or bench may conveniently stand upon it; care must be taken to leave no sharp edges about the stool. For a representation of one, see plate letter W.

The next instrument necessary for the electrical physician is a coated jar, furnished with Mr. Lane's electrometer. This instrument is made in the following manner. From the wire extending beyond the mouth of the jar, at about four inches from the upper extremity, let a piece of glass or baked wood three inches long, project at right angles. At the outer extremity of this stem let another piece of baked wood three inches long, be fixed parallel to the rod of the jar; the upper end of the parallel stem must be furnished with a brass socket, through which a graduated wire may easily pass. This wire must be furnished with a knob upon the end which is next the jar, and a hook or ring at its other extremity, to which a chain connected with the outer coating of the jar must be attached. From this construction it is readily perceived that the force of the discharge or shock, will be proportioned to the distance of the ball of the electrometer, and the usual ball of the jar; i. e. when the shock is large it will pass from one knob to the other at a larger distance, and when small at a smaller distance, and thus the distance will be the measure of the shock.—The next thing to be provided is a ball, either of metal, or of wood covered with tin foil; this must have a metallic handle, which may be sepa-

rated from the ball at pleasure, having at one of its extremities a sharp point to receive a stream of electric fire; small pointed pieces of wood made in a conical shape, may be fixed on this point, when the patient requires a degree of electricity between a spark and a stream.

The bottle director is the next instrument to be described. It is exactly the same with the common Leyden phial, with the addition only of a hook cemented to the bottom. To use this director (suppose for instance you wished to pass a shock through the arm) let a communication be made between its inner coating and the prime-conductor, by which means it will be charged; then let a chain be fastened, by one end, to the hook which is at the bottom; then by applying the other end of the chain (which may be furnished with a ball) to one side of the arm, and the knob of the jar to the other, a shock will be given.

These are the instruments for the electrical physician. We are now to describe the manner in which electricity may be applied to the best advantage.

1st. By simply placing the patient upon the electrical stool. While the machine is in action the patient constantly emits the overplus of the electric fluid that he receives, which continually passes off from every part of his body, and produces a salutary effect. It may be suspected that so gentle a treatment could have but little influence. It is however upon good authority we assert, that nervous and sedentary persons have derived considerable advantage from this mode of application.

2d. By electric friction. Let the part affected be covered with a piece of flannel or woollen cloth, and place

the patient upon the insulated chair, and connect him with the prime-conductor; then take a metallic ball, communicating with the earth, and rub it over the flannel or woollen cloth. Electricity thus applied has often removed violent spasms, and many other afflicting complaints.

3d. By drawing sparks. Let the patient, as in the last instance, be placed upon the insulated stool, and connected with the prime-conductor; then bring the metallic ball, communicating with the ground, within about half an inch of the part affected, and sparks will pass from it to the ball. Cutaneous eruptions, scrophulous tumours and deafness, are frequently benefitted, and sometimes removed, by this method of application. Deafness, in particular, has been entirely cured by the electric spark, when every other remedy has proved ineffectual. One of these cases came under our own observation. A gentleman who was affected with an almost total loss of hearing for more than six months, was advised by his physician to make a trial of electricity as a remedy. He applied to us, and was under our care about four or five weeks, when he left us almost entirely recovered. This gentleman was treated in the following manner.

We placed him on an insulated chair communicating with the prime-conductor. Then, with a blunt pointed wire inserted into a glass tube, we drew sparks from the *meatus auditorius*. This operation was continued for eight or ten minutes, at every visit. He commonly attended us twice or thrice a week. We were fully persuaded that the cure would have been more speedy, if he had received the electricity more frequently.

4th. By the stream. Place the patient as in the two last instances; then bring the point, instead of the ball, near the part affected. When the electrical stream is to be applied the wooden point is preferable to the metallic one. Inflammations and other diseases of the eyes, and several other disorders, have been thus removed.

5th. By the director. Place the patient on a chair—insulation in this case being unnecessary. Then lay the ball, which communicates with the outside coating of the director, upon the affected part; after which, bring the director, which must have been previously charged, near any other part of the body, and the intended operation will be performed. It is impossible to tell the precise quantity of electricity which ought to be administered in every complaint, because persons who are affected with the same disease will sometimes require very different degrees of electrization, which must be judged of by the nature of their constitution, their habits of body, and other circumstances. Small sparks will sometimes have more effect upon a delicate and irritable constitution, than pretty powerful shocks upon others. The Leyden phial, with Mr. Lane's electrometer, is the most convenient instrument for sending shocks of different powers through particular parts of the body.—To use this—Let the wire of the electrometer be placed at the proper distance for the required shock; connect a chain or wire, communicating with this, with the part affected—and let a communication be made between any other part of the body and the outside coating of the phial. Now turn the cylinder, and the phial, when it has received the proper charge, will discharge itself through the circuit formed by the chains or wires, and

the part of the patient which was to be subjected to the shock.

CHAP. XIX.

Directions concerning the use of the electrical apparatus, with some practical rules for performing experiments with it to the best advantage.

The machine described in Chapter IV, or one similar to it, is capable of exhibiting the principal electrical phenomena, provided it be skilfully managed; but without such management it will constantly disappoint the electrician, and prove of little use. Let the following directions and observations, then, be attentively regarded.

1. Keep all the instruments as free as possible from dust and moisture.

2. When the weather is clear, the air dry and a little cold, the electric fire may be easily and copiously collected. But when the weather is hot or damp, the electrical machine is much less powerful.

3. Before the machine is used, the cylinder should be wiped clean, with a linen cloth that is soft, dry, and warm; after which a clean hot piece of flannel, or old silk handkerchief, may be applied with advantage.—This done, if the cylinder be turned pretty fast, when the prime conductor and other instruments are removed, the electricity, upon applying the knuckle or other conductor, will issue from the glass with a crackling noise, accompanied with sparks; this indicates the machine to be in good order, so that the electrician may proceed to perform his experiments. But if, when the

cylinder is turned and the knuckle applied, no sparks be perceived, then the fault is most probably in the rubber. If so, it must be removed and held to a fire, so that its silk part may be dried. Then take a little tallow from a candle and just pass it over the leather of the cushion, after which spread upon it, a little amalgam, and force it as much as possible into the leather. Replace it, and let the cylinder be again wiped; the machine is fit for use.

4. Sometimes the electric matter will not be well collected, because the machine is not sufficiently supplied with it from the earth; which happens, when the table upon which the electrical machine is placed and to which the chain or wire of the rubber is connected, is very dry, and consequently a bad conductor. In this case, the best method is to connect the chain or wire of the rubber with some moist ground, or with the iron-work of a water-pump, if convenient. Thus the rubber will be supplied with as much of the electric fluid as is required.

5. When the cylinder is very hot (say above 110° of Fahrenheit's thermometer,) it will not collect the electric fluid well.

6. When a sufficient quantity of amalgam has been accumulated upon the leather of the rubber, and the machine does not work well, then, instead of putting more upon it, a small quantity of that which is already on the leather must be taken off.

7. After the cylinder has been used for some time it will contract black streaks, which continually increase, and greatly obstruct its electric power.—These streaks must be taken off, and the glass frequently wiped to prevent their being again formed.

8. Coated jars, before they are used, ought to be made a little warm. If this be done, they will receive and retain the charge much better.

9. If one of the jars of a battery, as is sometimes the case, make a spontaneous discharge prematurely, it will of course discharge the whole battery; and in such case the faulty jar should be exchanged for one which is free from this defect.

10. In making the discharge of an electrical battery, or of a single jar, the electrician must be careful not to place the discharging-rod upon the thinnest part of the glass, as that may cause the bursting of the jar.

11. In large batteries, some of the jars frequently burst in the discharge. To remedy this inconvenience, Mr. Nairne says that the discharging-rod should never be made of a good conducting substance, except the circuit be at least five feet long. But here it may be remarked, that the length of the circuit weakens the force of the shock proportionably; the highest degree of which is in many instances required. When a coated phial is cracked, either by a spontaneous discharge or otherwise, the outside coating must be removed from the fractured part; then make it moderately hot by holding it near the fire; in this situation apply burning sealing-wax to the part, so as to cover the fracture completely, taking care that the thickness of the wax be rather more than the thickness of the glass; lastly, cover all the sealing-wax, and part of the glass beyond it, with a composition made of four parts of bee's-wax, one of rosin, one of turpentine, and a little oil of olives: which composition must be spread upon a piece of oiled silk, and applied in the form of a plais-

ter. In this manner jars which have been broken may be repaired effectually.

12. When a jar, and especially a battery, has been discharged, the wires ought not to be touched with the hand before the discharging-rod has been applied a second, and even a third time; as there generally remains a residuum of the charge, which is sometimes very powerful. This residuum is in a great measure occasioned by the electricity, which, when the jar is charging, spreads itself over the uncoated part of the glass, and which is not discharged at first, but gradually returns to the coating after the first discharge is made.

13. When an experiment is to be performed which requires only a small part of the apparatus, the remaining part should be removed from the table.—Candles should never be placed near the prime-conductor; for the effluvia of their flames carry off much of the electric matter.

14. One or two inches of the lower part of a Leyden phial should be coated with some thick paint, in order to prevent the amalgam, which is often scattered upon the table, from corroding the tin-foil, and thereby diminishing the charge.

15. When a prime-conductor is used, those sparks are strongest which are taken from the extremity farthest from the cylinder.

16. The longest sparks are drawn from any conductor along an electric substance. Thus, if the conductor be supported by pillars of glass or baked wood, the longest sparks may be taken close to the pillar. If the conductor be bent a little inward, so as to make the surface concave, a particularly large and undivided spark may be drawn from that place: but where the

surface is convex, the spark is more apt to be divided and weakened.

17. It sometimes happens that cylindric or globe machines do not work well, owing to the air within them being too much rarefied by the heat of the cement, when the caps are fixed on. To remedy this, a small hole may be bored through one of the caps, so as to admit air into the cylinder or globe.

18. If the electric by any means become scratched, the working of the machine will be greatly impeded, if not altogether prevented. This is accounted for upon the principle that smooth and rough glass electrify differently when excited by the same rubber, and the two different states destroy one another. This may be remedied by filling up the scratches with a little tallow.

EPITOME

OF

ELECTRICITY.

DIVISION II.

CHAP. I.

Entertaining Experiments, made by electrical Attraction and Repulsion.

ELECTRIC attraction and repulsion, observed in excited amber, was, as we have already had occasion to remark, the first phenomenon which was noticed in the science of which we treat. We have also hinted that, to the present time, no explanation of this attraction and repulsion which is entirely satisfactory, has been given. Facts, however, are known in abundance; and certain principles, relative to this part of our subject, are clearly ascertained. To exhibit and illustrate these has been our object in selecting the following experiments; some of which may be considered as intended chiefly for amusement, but all of which, if thoroughly comprehended, will serve to fix the principles of the science more deeply in the mind of a learner.

EXPERIMENTS.

The self-moving Wheel.

This machine was invented by Dr. Franklin. It is made of a thin round plate of window-glass, 17 inches in diameter, covered on both sides with tin-foil, except about two inches next the edge. Two small hemispheres of wood are cemented to the two sides centrally opposite, and in each of these a strong thick wire eight or ten inches long is placed; and these form the hub and axis of the wheel. It turns horizontally on a point at the lower end of its axis, which must be insulated. The upper end of the axis, passes through a hole in a thin plate of brass, cemented to a strong piece of glass or baked wood, which keeps it six or eight inches distant from any non-electric, and is furnished with a ball of wax or metal on the top, to keep in the fire. In a circle on the table which supports the wheel, are fixed twelve small pillars of glass about four inches apart, with a thimble or metallic ball on the top of each. On the edge of the wheel is a small metallic bullet, communicating by a wire with the upper coating of the wheel; and about six inches from it, is another bullet communicating, in like manner, with the lower coating. When the wheel is to be charged by the upper coating, a communication must be made from the under one to the table. When it is well charged it begins to move; the bullet nearest to a pillar is attracted by the thimble or bullet on that pillar and passing by, electrifies it, and is immediately repelled from it; the succeeding bullet, which communicates with the other coating of the glass,

more strongly attracts that thimble, on account of its being previously electrified by the other bullet; and thus the wheel increases its motion, till its velocity is regulated by the resistance of the atmosphere.—The wheel will turn half an hour, and make, one minute with another, 20 turns in a minute, which is 600 turns in the whole; the bullet of the upper coating giving, in each turn, 12 sparks to the thimbles or balls, which make 7200 sparks; and the bullet of the under coating receiving as many from the thimbles; those bullets moving in the time near 2500 feet. The thimbles are well fixed, and in so exact a circle, that the bullets may pass within a very small distance of each of them. If, instead of two bullets, there be eight, four communicating with the upper, and four with the under coating, placed alternately, the motion will be considerably increased, but then it will not continue so long. These wheels may be applied to the ringing of chimes, and the moving of light-made orreries.

The electrical Dance.

Suspend from the prime-conductor, by means of a hook, a metallic plate, six inches in diameter. About three or four inches from this, and directly under it, place another plate of the same kind, communicating with the earth. Upon the lower plate, throw small painted figures of men and women, cut in paper, or made of the pith of elder. Now, if the cylinder be turned, the figures will begin to move between the plates, leaping from one to the other, with surprising velocity, exhibiting many curious and ludicrous attitudes and motions.

The electrified Bells.

The phenomena of attraction and repulsion may be very satisfactorily shown with the electrified bells. In order to make this experiment, provide yourself with a piece of wire, furnished with a hook equidistant from both ends, and by which it may be suspended from the prime-conductor. At each end of this wire suspend a small bell by a chain or wire; and from the middle point between these two bells, suspend a third, by a silk thread; let a clapper be hung between each of the bells, also by silk threads. From the concave or under side of the middle bell let a chain proceed, communicating with the table, and having a silk thread at its extremity. Now if the cylinder of the machine be turned, the clappers will fly from bell to bell with a very quick motion, and the bells will ring as long as the electrization continues.

The two outer bells, being suspended by chains or wires, are electrified first; hence they attract the clappers; and having communicated to them part of their electricity, repel them. The middle bell, which is in its natural state, now attracts them, and deprives them of their acquired electricity; after which they are again attracted by the outer bells, and again repelled. If, by holding the silk thread, the chain of the middle bell be raised from the table, the bells, after ringing a short time, will stop; because the middle one, being insulated, will soon become as strongly electrified as the other two; in which case, the clappers being equally attracted by both bells, must discontinue their motion towards either.

If the experiment be made in a darkened room, a spark will be seen between the clapper and bells, at every stroke.

This experiment will have a better effect, if, instead of keeping the machine in motion, a charged jar be placed in contact with the prime-conductor; and when joined with the preceding experiment, the whole will have the appearance of an *electrical ball.*

The inflammable air Balloons.

The following experiment may serve to illustrate some of the phenomena observed in thunder storms.

Provide two balloons, made of the allantoides of a calf, containing about two cubic feet, and fill them with inflammable air. To each of these attach, by a silk thread about eight feet long, a weight sufficient to prevent their rising higher than the above distance in the air. Then connect one of them with the positive, and the other with the negative conductor, or insulated rubber of the machine, by very thin wires, thirty feet long: keep them a considerable distance asunder, and as far from the machine as the wires will admit. On being electrified, the balloons will rise as high in the air as the silk thread will allow them, then attract each other, and uniting as it were in one cloud, will gradually descend.

The rising of these balloons is attributed to the expansion of the air contained in them, in consequence of the repulsive power communicated to its particles by the action of the electric matter upon them.—When in contact, their opposite electrical powers destroy one another, and they descend in consequence of the condensation of the internal air.

Dr. Franklin's Experiment for illustrating his Theory of Thunder Storms.

Take two round pieces of paste-board, two inches in diameter; from the centre and circumference of each of them suspend, by fine silk threads eighteen inches long, seven small balls of wood, or seven peas, equal in size, so that the balls appended to each paste-board will form equilateral triangles, one ball being in the centre and six at equal distances from that, and from each other, around the circumference. Thus they represent particles of air. Dip both setts in water; and some of it adhering to each ball, they will represent air loaded with moisture. Electrify one sett, and its balls will repel each other to a greater distance, enlarging the triangles. Could the water, supported by the seven balls, come in contact, it would form a drop or drops, so heavy as to break the cohesion it had with the other balls, and so fall. Let the two setts then represent two clouds, the one a sea-cloud electrified, and the other a land-cloud. Bring them within the sphere of attraction, and they will instantly draw towards each other. Now you will see the separated clouds close thus—the first electrified ball that comes near an unelectrified one, by attraction joins it, and gives it fire; instantly they separate, and each flies to another of its own party, one to give and the other to receive fire; and so they proceed through both setts, but so quick as to be in a manner instantaneous. In the collision they shake off and drop their water, which represents rain.

CHAP. II.

Experiments with electric Light.

THESE experiments should be made in a darkened room, for though the electric light is visible frequently in day light, yet the appearance of it is very often confused, so that a distinct idea of it cannot be formed.

Before we proceed to describe the experiments under this head, it will be necessary to inform the reader that by the term *vacuum* which he will frequently meet with in this chapter, we mean such an one as is formed by the action of an air pump, which is a good conductor of electricity.

EXPERIMENTS.

The Aurora Borealis.

Take a phial nearly of the shape and size of a Florence flask; fix a stop-cock or valve to its neck, and exhaust it of air.—If this phial be rubbed in the usual way to excite electrics, it will appear luminous within, being full of a flashing light, very much resembling the northern lights or aurora borealis. This phial may also be made luminous by presenting one end of it to the prime-conductor, while the other is held in the hand. In this case, the whole cavity of the glass will instantly appear full of a flashing light, which remains in it for some time after the glass has been removed from the prime-conductor.

A glass tube exhausted of air in the same manner, and hermetically sealed, may be used instead of this phial, and perhaps with more advantage.

The most remarkable circumstance attending this experiment is, that after the phial or tube has been removed from the prime-conductor, and even several hours after the flashing light has ceased, strong flashes will be again visible upon applying the hand.

The causes of this phenomenon are two; first, the conducting nature of the vacuum; and second, the charging of the glass; for when one side of the phial is touched with the prime-conductor, the electric fluid communicated to that part on the outside, occasions the natural fluid of the inside surface, to leave its place and pass to the opposite side of the phial, which does not communicate with the electrified conductor; this passing of the fluid through the vacuum occasions the light within, which is more or less subdivided as the vacuum is more or less perfect.

That part of the phial which has touched the prime-conductor is actually charged, for its outer surface has acquired an additional quantity of the electric fluid, and the inside has lost part of its natural quantity; but as the outside of the glass has no coating, when it is removed from the prime-conductor and is not in contact with the hand or other conductor, the charged part will be discharged gradually, that is, while its outside surface is communicating its redundant quantity to the contiguous air, the inner surface acquires the electric fluid from the other parts of the phial or tube, and this fluid passing through the vacuum, causes the light which is observed for so long a time. If the phial or

tube be grasped with the hand, the discharge will be accelerated, yet it cannot be effected in this way immediately, because the hand cannot touch every part of the glass at once.

The Leyden Vacuum.

Take a small phial and coat it, about three inches up the outside, with tin-foil. At the mouth of this phial cement a metallic cap, having a hole with a valve; and from this cap let a wire proceed a few inches within the phial, terminating in a blunt point. When this phial is exhausted of air, a metallic ball must be screwed upon the cap, so as to defend the valve, and prevent the air from getting into the phial. The reason why this phial requires no inside coating, is, because the electric fluid pervades a vacuum, so that it can pass very easily from the wire to the surface of the exhausted glass, without the assistance of a non-electric coating.

This phial exhibits very plainly the direction of the electric matter, both in charging and discharging, for if it be held by its bottom, and the ball be presented to the prime-conductor, positively electrified, you will perceive that the pencil of rays (which always appears when the body is positively electrified, or is giving out the electric matter) will proceed from the wire within the phial, and when it is discharged, the star, (which always indicates that the body is negatively electrified, or is receiving the electric fluid) will be seen on the point instead of the pencil, but if the phial be held by the ball, and its bottom be presented to the prime-conductor, the contrary will take place.

The luminous Conductor.

This instrument, as well as the preceding, is an invention of Mr. Henley's and also shows the direction of the electric fluid passing through it. The description of it is as follows. To each end of a glass tube, about eight inches long and three or four inches in diameter, is cemented a metallic cap, so as to be perfectly air tight. A point projects from one of the caps, by which it is to receive the electricity from an excited cylinder, and from the other proceeds a wire, terminated by a ball, from which sparks may be taken. Each cap is furnished on the inside with a knobbed wire, which extends some distance into the tube. A stopcock or valve must be adapted to one of the caps, by which the tube may be exhausted of air.

The supporters of the instrument are two glass pillars, fastened to a bottom board.

When the tube is exhausted of air, and its pointed end placed near the excited cylinder of an electrical machine, the point will appear illuminated with a star, and a weak light will be seen pervading the whole tube ; but from the knobbed end of the wire, within the tube, a lucid pencil will issue, and the opposite knob will be illuminated with a star or round body of light, which, as well as the pencil of rays from the other knob, will be discernible among the other light which occupies the cavity of the tube. If the point, instead of being presented to the cylinder, be connected with the rubber, the appearance will be reversed—the reason is too obvious to mention.

If the wires within the tube be pointed, the illumination will be the same; but it seems not so strong in this as in the other case.

The electric Light flashing between two metallic Plates.

Let two persons (one standing upon an insulated stool communicating with the prime-conductor, and the other upon the floor,) each hold in his hand a polished metallic plate, in such a manner that their surfaces may be parallel, and about two inches asunder. Upon turning the cylinder, you will see the flashes of light between the two plates, so dense and frequent, that you can easily perceive any thing in the room.

By this experiment the electric light is exhibited in a very copious and beautiful manner, and bears a strong resemblance to lightning.

The spiral Tube.

This instrument is composed of two glass tubes, one within the other, and furnished with a metallic ball at each end. The innermost tube has a spiral row of small round pieces of tin-foil, stuck upon its outside surface, and lying at the distance of one thirteenth of an inch apart. Now if the tube be held by one of its extremities, while the other is presented to the prime-conductor, every spark that is received from the conductor, will cause small sparks to appear between all the round pieces of tin-foil upon the inner tube, which in the dark appears encompassed by a spiral line of sparkling fire.

Small pieces of tin-foil are sometimes stuck upon pieces of glass, so as to represent various fanciful figures, and upon the same principle is the luminous *word* produced.

To make an electric Spark visible in Water, and to render various other Substances luminous.

Fill a glass tube, about an inch in diameter and six inches long, with water, and to each extremity adapt a cork to confine the water; through the corks let two blunt wires pass, so as nearly to touch one another within the tube: connect the outside coating of a small charged phial with one of these wires, and touch the knob to the other, which will cause a vivid spark to appear between their extremities within the tube.

It is necessary in this experiment that the charge of the phial should be exceedingly slight, otherwise the tube would burst. If you place in a common drinking glass almost full of water, two knobbed wires, so that their knobs may be within a little distance of one another in the water, and make the charge of a large jar pass through the wires, the explosion will disperse the water and break the glass with surprising violence.—This experiment is very dangerous if not made with great caution.

Water may be made luminous thus. Connect one end of a chain with the outside coating of a charged jar, and let the other lie on the table; place the end of another chain at about one fourth of an inch from the former; then set a decanter of water on these separated ends, and on making a discharge of the jar through the chains, the water will appear beautifully luminous.

To render ivory or box wood luminous.—Place an ivory ball on the prime-conductor of the machine, and take a spark or send the charge of a phial through its center, the ball will appear perfectly luminous; but if the charge be not taken through the center, it will pass off the surface and corrode it.

A spark taken through a ball of box wood, not only illuminates it, but makes it appear of a beautiful crimson, or rather scarlet colour. An egg may also be illuminated in the same way.

But the most curious experiment to shew the electric light is made with the real, or more easily with the artificial Bolognian stone, invented by the ingenious Mr. J. Canton. This phosphorus is a calcareous substance (generally used in the form of powder) which has the property of absorbing light when exposed to it, and afterwards appearing lucid in the dark. To make the experiment, take some of this powder, and by means of spirits of wine or ether, stick it all over the inside of a clear glass phial, and stop it with a good cork and sealing wax. If this phial be kept in a darkened room, (which for this experiment must be very dark,) it will give out no light; but let two or three strong sparks be drawn from the prime-conductor, while the phial is kept about two inches distant from the sparks, so that it may be exposed to their light, and the phial will afterwards appear luminous for some time. The powder may be stuck on a board by means of the white of an egg, so as to represent figures of planets, letters &c. at the operator's pleasure, and these figures may be illuminated in the dark in the same manner as the phial, [for the method of making this phosphorus, see appendix, No. 5.]

CHAP. III.

Experiments with Charged Electrics.

EXPERIMENTS with charged electrics should always be made with caution, for though the discharge of a small phial through the body is seldom attended with bad consequences, yet that of a battery is always dangerous, and sometimes mortal. The operator should therefore be attentive, not only to the experiments he is about to perform, but also to the persons who may happen to be with him, forbidding them to come near any part of the apparatus.

EXPERIMENTS.

The Magic Picture.

This experiment was contrived by Mr. Kinnersley, and is thus described by Dr. Franklin.

Having a large mezzotinto with a frame and glass, (suppose of the king) take out the print and cut out a pannel of it, near two inches distant from the frame, all round. If the cut is through the picture it is not the worse. With thin paste or gum water fix the border that is cut off on the inside of the glass, pressing it smooth and close. Then fill up the vacancy, by gilding the glass well with leaf-gold or brass. Gild likewise the inner edge of the back of the frame all round, except the top part. Make a communication between that gilding, and the gilding behind the glass; then put in the board, and that side is finished. Turn up the glass and gild the foreside exactly over the back gilding, and

when it is dry paste on the pannel of the picture which has been cut out, observing to bring the corresponding parts of the picture and border together, by which it will appear of a piece, as at first (only part of it is behind the glass, and part before it.) Hold the picture horizontally by the top, and place a little moveable gilt crown upon the king's head. If now the picture be moderately electrified, and another person take hold of the frame with one hand, so that the fingers may touch the inside gilding, and with the other hand endeavour to take off the crown, he will receive a terrible blow. If the picture were highly charged the consequences might be as fatal as those of high treason; for when the spark is taken through a quire of paper, and the discharge of the picture is made through it, a fair hole will be perceived in every sheet, (though a quire of paper, is thought a good armour against the push of a sword, or even against a pistol bullet,) and the crack exceedingly loud. The operator who holds the picture by the upper end, (where the inside of the picture is not gilt,) to prevent its falling, feels nothing of the shock, and may touch the face of the picture without danger, which he pretends is a test of his loyalty.

If a ring of persons take the shock among them, the experiment is called "the conspirators."

Colours changed by the Electric shock.

Mr. Cavallo accidentally observing that an electric spark, passing over the surface of a card painted red, marked it with a black stroke, was induced to try what would be the effect of sending shocks over cards painted with different colours; accordingly he painted seve-

ral cards with different colours, and passed the discharge of a jar, containing about one foot of coated surface over them, the result of his experiments are the following—

Vermilion was marked with a strong black track, about one tenth of an inch wide. The streak was generally single, but sometimes divided in the middle.

Carmine received a faint and slender impression, of a purple colour.

Verdigrise was shook off from the surface of the card, except when it was mixed with a strong gum water, in which case it received a very faint impression.

White lead was marked with a strong black track, but not so broad as that on the vermillion.

On the red lead there appeared only a slight mark, much like that on the carmine.

The other colours he tried were orpiment, gambooge, sap green, red ink, Persian blue, and some others which were compounds of the first, but they received no impression.

It has frequently been observed that, when a flash of lightning strikes the mast of a ship, it passes over those parts of the mast, which are covered with lampblack and tar, or painted with lampblack and oil, without the least injury; when at the same time it shatters the uncoated part so as to render the mast entirely useless.—This singular fact induced Cavallo to carry his investigations on the subject still farther, particularly with a view to determine something relative to the properties of lampblack and oil. But it will not be necessary here to enumerate all his experiments upon this subject. It is sufficient to state that the two following propositions are the result of his observations.

" First—That a coat of oil paint over any substance defends it from the effects of an electric shock, that would otherwise injure it; but that it would by no means defend it from any shock whatever.*

" Second—One colour does not seem preferable to another, if it is equal in substance and equally well mixed with oil—but that a thick coating affords a better defence than a thin one."

To fire Spirit of wine.

Hang to the prime-conductor a short metallic rod, having a small ball at the end—then pour some spirit of wine, a little warmed, into a metallic spoon. Hold the spoon by the handle, in such a manner that the knob of the rod may be about an inch above the surface of the spirit.—In this situation, if by turning the cylinder a spark be made to pass to the spoon through the spirit, it will be set on fire.

It will generally be found more advantageous to fix a metallic dish, containing the spirit, upon the prime-conductor.

This experiment may be varied different ways, so as to render it very agreeable to a company of spectators. A person, for instance, standing upon an insulating stool, connected with the prime-conductor, may hold the spoon with the spirit, in his hand—another person, standing on the floor, may fire the spirit by bringing his finger within a small distance of it—or,

* This looks something like a contradiction: but we suppose Mr. Cavallo intended to say, that though the coat of paint does not prevent the shock from passing down the mast, it prevented the mast from being injured by the shock.

instead of his finger he may use a piece of ice, which will make the experiment still more surprising.

To swell Clay, and break small Tubes.

Roll up a piece of soft clay in a small cylinder, and insert two wires, so that their ends within the tube may be about one fifth of an inch apart.—If a shock be sent through this clay, by connecting the wires with the coatings of a pretty large jar which has previously been charged, the clay will be inflated, by swelling in the middle.—If the clay be not very moist, it will be broken by the explosion, and the fragments thrown about the room.

To make this experiment with a little variation, take a piece of the stem of a tobacco-pipe, or a glass tube (which will answer equally well,) and fill the bore with moist clay; then insert wires as in the preceding experiment, and send the shock through it. This tube will not fail to be broken, and the pieces thrown to a considerable distance.

To pierce Cards &c. with the electric Explosion.

Hold a card or the cover of a book, close to the outside coating of a jar, then by applying one end of the discharging rod to the card, discharge the jar; the electricity rushing through the circuit from the positive to the negative coating, will pierce a hole through the card, or book-cover. This hole will be larger or smaller as the card is more or less moist. The card, upon examination, will be found to have a sulphureous or rather

phosphoreal smell. It is remarkable in this experiment that there is a burr raised on both sides of the card.

Insects may be killed in this manner. If they are quite small the shock of a common phial will be found sufficient to deprive them of life: but if they are large, they will, upon receiving the shock, appear dead, but after a short time recover.—This however depends upon the quantity of the charge sent through them.

The shock of a jar, sent through a lump of white sugar, if strong enough to break it, will illuminate every part of the sugar, and this illumination will continue a short time after making the experiment.

To light a Candle by the discharge of a Jar.

Take a wire about the size of a common knitting needle, and by means of a small flexible chain, let one end communicate with the outside coating of a jar, containing at least ten inches of coated surface. To the other end of the wire some cotton must be twisted very loosely, so as to cover the extremity of the wire completely. The cotton must be rolled or sprinkled with powdered rosin. Now let the jar be charged and bring the cotton to its knob pretty quickly, so that the discharge may pass through the rosin on it; the cotton will instantly inflame, and will last long enough to light a candle.

Paper, dipped in a solution of nitre and water, and previously dried, may be fired in the same manner, and by this a brimstone match may be lighted. The same effect will follow, if you grease the cotton with a little sweet-oil, or moisten it with turpentine.—Flame may be again excited in a candle recently blown out, by

simply passing the discharge of a jar through the wick and smoke.

CHAP. IV.

Experiments relating to the influence of pointed Bodies on Electricity.

THESE experiments, though not the most entertaining are certainly among the most important in electricity. By the knowledge of them, mankind have received the greatest practical advantage. But as we have already treated of this subject, we shall, in this chapter, describe only two experiments which may serve to set it in a clearer light, and which may, in a more particular manner, demonstrate the utility of affixing pointed conductors to buildings, in order to preserve them from the dreadful effects of lightning.

EXPERIMENTS.

The electrified Cotton.

Take a small lock of cotton, extended in every direction as much as can conveniently be done, and by a linen thread about five or six inches long, fasten it to the prime-conductor; then let the cylinder of the machine be turned—the lock of cotton, by the repellency of its filaments, will immediately swell and stretch itself towards the nearest uninsulated conductor. In this situation, if you present your knuckle or a knobbed wire towards the cotton, it will immediately move towards it, and endeavour to touch it; now with the other

hand present a pointed wire to it :—the cotton will immediately shrink up, and fly towards the prime-conductor. Remove the point, and the cotton will again approach the knuckle or knobbed wire—present the point, and it will again recede.

This experiment shows that a point is the proper termination for a lightning rod. For the cotton will represent the cloud, and the two wires, the lightning rods with different terminations.

The cotton is attracted by the knuckle or knobbed wire, in order to part with its electricity, this however cannot be effected unless they come so near as to touch one another, and then the discharge is effected at once. But the point is capable of drawing off the electricity when at a distance, and it does this gradually; at the same time that it causes a current of air which repels the cotton; the cotton being deprived of its electricity is again attracted by the prime-conductor.

The electrified Bladder.

Coat a bladder that is well blown, with gold, silver, or brass leaf, which may be fastened on with gum-water.—Suspend this bladder at the end of a silk thread, six or seven feet long, from the ceiling of the room. Electrify the bladder by giving it a few sparks from a charged jar, and hold towards it, at some distance, a knobbed wire; you will perceive that the bladder approaches the knob, and when it comes within striking distance, gives it the electricity it received from the charged jar, and thus becomes discharged. Touch it again with the charged phial, and instead of the knobbed wire, present the point of a needle towards it, the

bladder will now be rather repelled than attracted, especially if the point be very suddenly presented to it.

CHAP. V.

Promiscuous Experiments.

WE shall in this chapter, describe a variety of experiments, which are easily made, and which may serve to illustrate the principles of electricity in general.

EXPERIMENTS.

The electrical Jack.

This is an invention of Dr. Franklin, and turns with considerable force, so that it may somtimes be used for the purposes of a common jack. The construction of it is as follows.—A slender shaft of wood passes, at right angles, through the centre of a thin, round board, about twelve inches in diameter, and turns upon a sharp point of iron, fixed in the lower end; while a strong wire in the upper end passes through a hole in a brass plate, which keeps the shaft truly vertical. About thirty radii, of equal length, made of sash glass, cut into narrow slips, issue horizontally from the circumference of the round board, the ends farthest from the centre, being about four inches apart, and each furnished with a metallic ball or thimble.

If the wire of a jar, electrified in the common way, be brought near the circumference of the wheel, it will attract the nearest ball or thimble, and put the wheel in motion. That ball or thimble, passing by the knob of

the jar, receives a spark from it, and being thereby electrified, is repelled, and driven forward; while the second, being attracted, approaches the knob, receives a spark from it, and is driven after the first. This process is repeated till the wheel has made one revolution; when the thimbles, before electrified, approaching the wire, instead of being attracted are repelled, and the motion presently ceases.—But if another jar, charged through the coating, or otherwise electrified negatively, be placed near the same wheel, its wire will attract the thimble or ball, repelled by the first jar, and thereby double the force which carries round the wheel.

The self-charging Tube.

Take a glass tube, about eighteen inches long, and an inch, or an inch and a half, in diameter; coat the inside with tin-foil, from one extremity of it as far as the middle; then fix a cork to the aperture of the coated end, and let a knobbed wire pass through it, and come in contact with the coating.

The instrument being thus prepared, hold it in one hand by the uncoated part, and with the hand clean and dry, or with a piece of buckskin, which has had some amalgam spread upon it, rub the outside of the coated part; after every two or three strokes, you must remove the rubbing hand, and by applying it to the knobbed wire, you will receive sparks from it. By this means the coated end will gradually acquire a charge, which may be increased to a considerable degree. Now, if you grasp the outside of the coated end with one hand, and touch the knobbed wire with the other, you will receive a shock.

In this experiment, the coated part of the tube answers the double purpose of the electrical machine and Leyden phial; the uncoated part serving as a handle, to hold the instrument by. The friction on the outside accumulates a quantity of positive electricity upon it, and this electricity, in virtue of its sphere of action, forces out a quantity from the inside. Then, by taking the sparks from the knobbed wire, this inside electricity is removed, and it consequently remains under-charged, or negatively electrified; and it also follows, that the positive electricity of the outside, comes closer to the surface of the glass, and begins to form the charge.

A small phial may be charged by giving the sparks from the knobbed wire of the tube to that of the phial; but the phial will be charged negatively, whereas the tube is charged positively.

To fire the electrical Cannon by inflammable Air.

This instrument consists of a metallic barrel, made in the shape of a common cannon,—a glass tube is cemented into the top of the barrel, in the place of a touch-hole, and through this tube a wire passes, which is bent so as to come within an eighth of an inch of the inner surface of the cannon,—on the outer end of this wire, a ball is fixed, which serves to receive a spark from a charged jar, or from the prime-conductor.

The inflammable air with which this cannon is to be fired, may be prepared in a common porter bottle, by mixing a handful of iron-filings with two wine-glassfuls of water, and an ounce of sulphuric acid, commonly called *oil of vitriol.* The air when thus made should be kept in a bottle closely stopped.

To use the instrument, have ready a cork, fitted to the mouth of the cannon,—uncork the bottle containing the air, and immediately apply the cannon to the mouth of the bottle; a sufficient quantity of the gas will rise into the cannon, in the course of a few seconds, when both the cannon and bottle must be corked. Now, if the knob of the wire passing through the tube be applied to the prime-conductor, so that a spark may pass through it to the inner surface of the cannon, the gas will be inflamed with a loud report, and the cork will be forced out with considerable violence.

Curious Figures made upon Glass, Paper, and other Substances, by means of Electricity.

Professor Lichtenburg first observed some curious figures made with pulverized rosin, on a large electrophorus; but since this original discovery, a variety of other methods have been contrived, for making them upon glass, paper, resinous substances and many others. The ingenious electrician may derive considerable information from these figures; their various appearances, in many instances, showing him the direction and quality of the electric fluid.

The principal method of making these impressions is to electrify a perfect or imperfect electric, and then to throw certain powders upon the electrified substance, which will be arranged in different forms. The most convenient method of projecting these powders is to put them into a small bottle of India-rubber, and then fasten a tube of glass or metal to the neck of the bottle; the orifice of this tube must be covered with a piece of flannel when used.

As to the nature of the powders, almost every substance which can be pulverized will do.—Thus chalk, rosin, sulphur, rose-pink, dragon's blood, gum-arabic, lake, and evaporated decoctions of colouring woods, may be used with advantage, either singly or mixed.

Take a clean pane of glass, fourteen or fifteen inches square, and after drying it thoroughly, hold it by one corner, and pass over its surface the knob of a jar, moderately charged with positive electricity—then, keeping it suspended, project upon it, by means of the bottle above described, a mixed powder of dragon's blood and gum-arabic, in equal parts. If you examine the glass, you will find that the two powders will be separated upon it, the red powder of dragon's blood falling on certain places, and the white powder of gum-arabic falling upon certain other places, so as to form a track upon the parts which were touched with the charged jar, consisting of two colours disposed in a thousand different ways.

If, instead of drawing the knob of the jar over the surface of the glass, you only touch it here and there with it, and then throw on the mixed powders as before, separate star-shaped figures will be formed about these places. The stars will be better defined when a single powder is used; their rays are sometimes few and strong; at others, many and slight, and frequently they do not go entirely round the parts which have been touched by the phial. These different effects depend chiefly upon the quantity of the charge in the jar.

If the jar be charged negatively, the appearances will be very different, from those occasioned by positive electricity. Very few rays will now be observed, the powders for the most part disposing themselves in round

figures, and generally a central spot of one powder will be surrounded by another of a different colour.

Some powders adhere but slightly to the glass, so as not to bear being touched; but if a piece of paper be laid upon the painted side, without disturbing the figures, and the edge of it be fastened all round to the edge of the glass, the figure may be preserved without injury. But a better method is to lay another pane of glass over the one with the figures upon it, and then to fasten them together with sealing-wax, or a piece of paper pasted over the edges.

If the powders of such colours as are used for enamel-painting be projected upon glass or porcelain, and these substances be afterwards exposed to a proper degree of heat, as that of an enameller's furnace, the figures will be rendered indelible.

Take a piece of common writing paper, and hold it near the fire, so as to make it quite dry and very hot—lay it upon a dry table and pass the knob of a charged jar over it—then take up the paper by one corner, and holding it suspended, throw upon it a mixed powder of dragon's blood and gum-arabic, in the way above mentioned.—The figures in this instance will be very beautiful, and may be made in various shapes, as letters, stars, or stripes. If the paper thus painted be held near the fire for a few seconds, the powder of dragon's blood, being a resinous substance, will be melted and fastened to the paper, after which the gum-arabic may be taken off.

Powders of different colours may be projected upon the paper after the same manner, but unless they be of a resinous nature, so as to be easily melted by heat, it is very difficult to fasten them to the paper.

A little experience will enable the operator to make them in a neat and handsome manner. It will however be necessary to observe a few precautions.—The charge of the jar should not be too great or too small; for in the former case the figures will be confused and irregular; and in the latter they will be too faint.—These experiments should be performed as quickly as possible, for if the paper be suffered to cool too much, or the communicated electricity be dissipated, the desired effect will not be produced.

The Electrified Cappillary Syphon.

Let a small bucket of metal be suspended from the prime-conductor, and put into it a syphon of glass or metal, so narrow at the outer extremity that the water may just drop from it.—Now, if the cylinder be turned, the water, which when not electrified came over only in drops, will run in a stream, or even be subdivided into a number of smaller ones.—If the experiment be made in the dark, the streams appear luminous.

The same phenomenon may be exhibited by a small bucket, with a jet pipe fixed in the bottom. This must be hung on the prime-conductor, as in the last experiment: or the experiment may be agreeably varied, by hanging one bucket from a positively, and another from a negatively electrified conductor: so that the two jets may be about three inches from each other.—The stream issuing from the one will be attracted by that issuing from the other, and both will unite into one: but, though both are luminous in the dark, before meeting, after this has taken place they will not be so, un-

less one of them was more powerfully electrified than the other.

The Lateral Explosion.

If a jar be discharged with a rod which has no electric handle, the hand which holds the rod, on making the discharge, frequently feels something similar to a shock, especially when the charge is considerable.—This shock, or lateral explosion, as it has been called, may be rendered visible in the following manner.—Connect a chain with the outside coating of a charged jar—then discharge the jar through another circuit; for instance, a discharging rod—The chain which is connected with the outside coating, but which forms no part of the circuit, will appear lucid in the dark; that is, sparks will be seen at every link. This chain will also appear lucid, if it be only put close to the jar, without touching it; and on making the discharge a spark will be seen between the coating and the end of the chain. This luminous appearance is what has been denominated the *Lateral explosion.*

To represent the Constellations.

Provide yourself with a piece of paste-board, of the size you intend the figure of the constellation, (four or five inches square will be found convenient) and cover one side with tin-foil or silvered paper. Let needles, or any other small metallic points, project from the other side of the paste-board, from the places where you intend stars to appear, taking care to form a communication between each of the points, or needles, and the

tin-foil on the other side. If the instrument thus prepared be fixed upon the prime-conductor, negatively electrified, all the points will be illuminated at once.—The experiment may be performed with the prime-conductor positively electrified; but in this case, the light at the points, being in the shape of a divergent cone, does not appear so proper to represent stars, as the round globular lights, which are characteristic of points negatively electrified.—It is scarcely necessary to remark that this experiment should be performed in a darkened room.

The Electrical Snake.

Cut a circular piece of silvered paper into a spiral form. The outer end must be shaped like a serpent's head, with the mouth open and the tongue protruded. Then provide an upright shaft of wood or metal, terminating upward in a point, and having the lower extremity fastened in a foot or bottom-board. The snake, being put spirally round the shaft, with its tail on the point, and then placed under a metallic point suspended from the prime-conductor, will turn round, and in a darkened room will appear to spit fire.

The luminous Shower.

Electrify a common tumbler, by passing a chain, communicating with the prime-conductor, over its inner surface. Place a small heap of steel or brass-filings on an uninsulated conductor, and invert the electrified tumbler over it: the filings will be attracted up the sides of the tumbler, and then thrown off. This, at night,

forms a very beautiful experiment, as the filings become luminous, and appear like a shower of fire.

If a tumbler, electrified in this way, be inverted over pith-balls, instead of brass-filings, the balls will leap with surprising velocity up the sides of it.

The luminous Discharging-rod.

Provide a glass tube in the shape of a common discharging-rod, about ten inches in length, and let the bore of the tube be nearly the eighth of an inch in diameter; upon one end fasten with cement, or otherwise, a brass knob, so as to be perfectly air-tight. Now expel the air from the tube, by heat or the air-pump, and then fix another knob upon the open end, in a way similar to the former.

If the instrument be used as the common discharging-rod, it will be found to answer its purposes equally well; while at the same time all the inner surface of the tube, during the discharge of a jar with it, is beautifully luminous.

Mr. Nairne also contrived a luminous discharging-rod. It consisted of an arched glass tube, with a metallic ball at each end, and a communication from one ball to the other was made by a brass chain, which passed through the bore of the tube.—In the discharge of a jar with it, small sparks are seen between the links of the chain within the tube.—Both these dischargers should have handles fastened to them.

To decompose Water by Electricity.

Let a glass tube, having a small bore, be filled with water; then close each end of the tube with a piece

of cork, and let two wires pass through the corks, so that their extremities may come pretty near each other within the tube.

If sparks of electricity be made to pass between the ends of the wires, within the tube, the water will be converted into oxygen and hydrogen gases.

If this process be continued till the extremities of the wires become immersed in the two gases, they will explode and again form water.

The Electrified Fountain.

Insulate a small fountain made of metal, (one on the construction of *Hiero's* will be found most convenient,) and connect it with the prime-conductor—put it in operation—the jet will be undivided, except at the top—now turn the cylinder, and you will immediately perceive the jet divided much lower than at first; the drops, which before fell nearly perpendicularly, will now be thrown off in elliptical lines, and attracted by any conductor brought near them. A small Leyden phial may be charged at the top of the jet, which will present the curious spectacle of fire coming out of water.

EPITOME

OF

ELECTRICITY.

DIVISION III.

CHAP. I.

Introductory Observations to the theory of Electricity.

THERE is scarcely any thing to which an inquisitive mind, such as a philosopher possesses, submits with more reluctance, than to the inability of assigning the causes of the most interesting appearances or phenomena of nature. That every effect has a cause, is a first or self evident principle, and the mind is not easily brought to acquiesce in its utter ignorance of the cause, when the effect is visible and striking.—From this circumstance proceeded the numerous wild, fanciful, and delusive systems of natural philosophy, which existed before the time of the great Lord Bacon.—His penetrating and discriminating mind saw that nothing solid could ever be achieved in that noble science, unless such a procedure were relinquished;—unless men would consent to confess their ignorance of causes which were actually unknown;—unless they would

cease to rely on hypotheses, however plausible, until they were verified by experiment;—consent to take facts as they are found, and by experiments alone endeavour to ascend to their causes. On this immoveable base the Newtonian philosophy is founded, and it will of course prove as durable as nature herself.

Two things, however, in regard to this subject, are of some importance to be remarked.—The first is, that experiments may sometimes be supposed to ascertain causes which will afterwards be found not to exist, or to be wrongly assigned; because the experiments had not been accurately or extensively made.

The second remark is, that though hypotheses are not to be taken for philosophy, till they have stood the test of experiment; yet in the process of the mind in making discoveries, hypothesis is perhaps always used, where the discovery is not merely accidental. No man can rationally make experiments till he has conceived a notion, supposition, or hypothesis in his mind, which he imagines experiment may serve to verify.—It is this which prompts him to his researches and guides him in conducting them.

In regard to electricity, it is remarked by Dr. Priestley, that "no other part of the whole compass of philosophy affords so fine a scene for ingenious speculation. Here the imagination may have full play, in conceiving of the manner in which an invisible agent produces an almost infinite variety of visible effects. As the agent is invisible every philosopher is at liberty to make it whatever he pleases, and ascribe to it such properties and powers as are convenient for his purpose. And, indeed, if he can frame his theory so as really to suit all the facts, it

has all the evidence of truth, that the nature of things can admit."

For ourselves we are by no means satisfied that there is yet any theory of electricity which will "suit *all* the facts;" and therefore if this be requisite to entitle a theory *philosophy*, as contra-distinguished from *hypothesis*, we must think that the best theory of electricity is yet hypothesis, and not philosophy. We believe that the Franklinian theory accounts for *more* facts, and is far more plausible, than any other. But, as we have already had occasion to remark in a former chapter, it does not appear to us fully and satisfactorily to account for all the phenomena of electric attraction and repulsion. Dr. Franklin always spoke with great diffidence of his own theory, and always denominated it an hypothesis.

"Every appearance, says he, which I have seen, in which glass and electricity are concerned, are, I think explained with ease by this *hypothesis*. Yet, perhaps, it may not be a true one, and I shall be obliged to him who affords me a better." In like manner Æpinus, who adopted the theory of Franklin, and who has illustrated its leading principles in a far more masterly and scientific manner than any other writer, still denominates the theory which he maintains an *hypothesis*. Why should pupils affect to go farther than their masters? We think that the theory of electricity is still an hypothesis. We are however clearly of opinion that the hypothesis of Franklin is preferable to every other. We have therefore adopted it in the whole of our system, and mean to close this division of our subject by giving it, somewhat in detail, with the leading facts and considerations by which its claim to superiority appears to us to be sup-

ported. In the mean time, as every student of electricity may wish to know, and ought to know, what other theories have been adopted, we shall fill the following chapter with a brief and compendious recital of some of the principal of them.—It would be endless to recite them all. We shall, however, enter into no extensive argument to prove their fallacy, as this would be inconsistent with our plan, as well as unprofitable in itself. We shall afterwards say what we can to confirm the theory of Franklin, and if we succeed, every thing opposed to it, must, of course, appear to be unsupported.

CHAP. II.

Theories of Electricity, exclusive of that of Franklin.

THE first electricians supposed that the attraction of electric substances, was caused by certain *unctuous effluvia*, emitted from these substances when they were excited. Such effluvia were supposed to fasten upon all bodies which fell in their way, and if not too heavy, to carry them back to the emitting substances. For at that time, all effluvia were supposed to return to the bodies whence they had been emitted; because they could not otherwise account for the fact, that such substances were not sensibly wasted by emitting effluvia. But when the subtilty of light was demonstrated by Newton, and that of the effluvia of many bodies was better understood, philosophers gave up the doctrine of the return of effluvia, both with regard to electricity and other subjects.

2. They applied to electricity the general, but unknown *principles of attraction and repulsion*—properties

which they supposed to be immediately communicated by the Creator to certain bodies. But the laws of this attraction and repulsion, in regard to electricity, we do not know that they attempted to explain.

3. Mr. Du Faye discovered the two opposite species of electricity, which he termed the *vitreous* and the *resinous*, because one was found in glass and the other in rosin, sealing-wax, &c. He immediately adopted the theory of *two distinct electric fluids*, repulsive with respect to themselves, and attractive of one another. But he did not know at this time, that both these species were concerned in every electrical operation, and that glass or rosin alone always produces both of them. When he found that electric appearances took place at an insulated rubber, and it was demonstrated that the action of the rubber did not produce, but only collect the electric fluid, he perceived that both electricities, as they had heretofore been called, were produced at the same time, by one and the same electric; and with a candour that does him honour, he gave up his theory, and embraced that of Franklin, which was first suggested about this time.

4. With some, and particularly Mr. Wilson, the chief agent in all electrical operations is *Sir Isaac Newton's ether;* which is supposed to be more or less dense in all bodies, in proportion to the smallness of their pores, except that it is much denser in sulphureous and unctuous bodies. To this ether are ascribed the principal phenomena of attraction and repulsion. "On this theory, (says Dr. Priestley) I shall make no particular remarks, because I cannot say that I clearly comprehend it."

5. The ingenious Abbè Nollet, whose theory has been more the subject of debate than all the others, before Dr. Franklin's, supposes that in all electrical operations the fluid, (of which he admits there is but one) is thrown into two opposite motions; that the *affluence* of this matter drives all light bodies before it, by impulse, upon the electrified body; and that its *effluence* carries them back again. But he seems very much embarrassed in accounting for facts where both these currents must be considered as taking place at the same time, and in finding out expedients to prevent their impeding and interrupting the effects of each other. To obviate this great difficulty, he supposes that every excited electric, and likewise every body to which electricity is communicated, has two orders or kinds of pores, one for the emission of the effluvia, and the other for the reception of them.

The Abbè maintained this hypothesis with a zeal and ingenuity worthy of a better cause. For it is manifest at once, that the existence of such kinds of different pores in bodies, is a mere gratuitous assumption. Our senses do not inform us of the existence of any such pores, nor have we evidence of any kind that they even exist at all, unless we consider it as evidence of their existence, that they are necessary to account for the appearances on which the Abbè grounds his theory.

Yet this theory, with some modification, has been strenuously maintained, and has its sdvocates to the present day. They say that "in bodies positively electrified, there is a flux of electric matter, from their surface all round; that is, the fluid contained in their pores pushes out on every side, and communicates a similar motion to the electric fluid contained in the adjacent

atmosphere. This must of necessity very soon exhaust the body of its electric matter altogether, if it was not instantaneously supplied after every emission. But this supply is immediately procured from the surrounding atmosphere. The quantity sent off is instantaneously returned from the air, and a *vibratory motion or struggle between the air and electric fluid*, immediately takes place. The positive electricity therefore consists in a vibratory motion in the air and electric fluid; and the force of the vibration is directed *outwards* from the electrified body. In bodies negatively electrified, the fluid contained in the neighbouring atmosphere is directed *towards* the body so electrified. But it is certain, that this motion inwards cannot be continued unless there is also a motion of the fluid outwards from the body. In this case also, there is a vibratory motion, but the force of it is directed *inwards*, and as the source of it lies not in the body, but in the surrounding atmosphere, it manifests itself somewhat less vigorously." We have taken this account of the modification of the Abbè Nollet's theory from one who firmly believed it. But we cannot pretend to controvert it, because, (as Dr. Priestley says,) "we cannot say that we clearly comprehend it."

6. There are some who explain the phenomena of electricity upon *chemical* principles. They also believe in the existence of two distinct and positive fluids; but instead of a *mechanical* operation, they consider all their sensible effects as arising from *chemical* affinity and union. The following may serve as a specimen of chemical electricity. It is said—

(1.) "There are two kinds of electric ether, which exist either separately or in combination. That which is accumulated on the surface of smooth glass, when rubbed

with a cushion, is here termed *vitreous* ether; and that which is accumulated on the surface of resin, or sealing-wax, when rubbed in like manner, is here termed *resinous* ether; and a combination of them, as in their usual state, may be termed *neutral* electric ethers.

(2.) Atmospheres of vitreous, or of resinous, or of neutral electricity, surround all separate bodies, are attracted by them and permeate those which are called conductors, as metallic, aqueous, and carbonic substances; but will not permeate those which are called non-conductors, as air, glass, silk, resin, sulphur.

(3.) The particles of vitreous ether, strongly repel each other, but attract the particles of resinous ether and *vice versa*. When the two electric ethers unite, a chemical explosion occurs, in some respects like that of gun-powder, light and heat are liberated, and rend or fuse the bodies which they occupy.

(4.) Glass holds within it, in combination, much resinous electric ether, which constitutes a part of it, and which more forcibly attracts vitreous electric ether, from surrounding bodies which stand on it, mixed with a less proportion of resinous ether, like an atmosphere, but cannot unite with the resinous ether, which is combined with the glass. And resin, on the contrary, holds within it, in combination, much vitreous electric ether, which constitutes a part of it, and which more forcibly attracts resinous electric ether from surrounding bodies, which stand on it, mixed with a less proportion of vitreous ether, like an atmosphere, but cannot unite with the vitreous ether which is combined with the resin.

(5.) Hence the non-conductors of electricity are of two kinds, and opposite to each other; the one class of the

vitreous, and the other of the resinous. But the most perfect conductor, such as metal, water and charcoal, having neither kind of electric ether, *combined* with them, though *surrounded* with both, suffer both kinds to pass through them easily.

(6.) Great accumulation or condensation of the separate electric ethers, attract each other so strongly that they will break a passage through non-conducting bodies. Hence trees and stone walls are rent by lightning.

(7.) When artificial or natural accumulations of these separate ethers are in a very small quantity or intensity, they pass slowly and with difficulty from one body to another, and require the best conductors for this purpose. Whence many of the phenomena of the Torpedo, the Gymnotus, and of Galvanism.

(8.) The electric ethers may be separately accumulated, by the contact of conductors with non-conductors—by vicinity of the two ethers—by heat—and by decomposition.

(9.) When these two ethers unite suddenly and with explosion, a liberation of light and heat takes place, as in all chemical explosions. Accordingly it is said that a *smell* is perceptible from electric sparks, and even a *taste*, which must be supposed to arise from new combinations or decompositions."

The theory founded on the principles above stated is supposed, by those who adopt it, to solve many difficulties which can scarcely be accounted for on the theory of Franklin.

Dr. Gibbes also adopts a chemical theory of electricity. He supposes that oxygen gas is produced by the union of *positive electricity* with water; and hydrogen

gas by the union of *negative electricity* with water: and that water, uniting in different proportions with the two electricities, is the ponderable part of all the elastic fluids. He asserts that by the *positive electricity* metals are oxydated, and blue vegetable colours reddened; and also that the acidifying effect of electric commotions in the atmosphere, on weak fermented liquors, is unquestionable.—On the other hand, according to this writer, by *negative electricity* the vegetable blue is restored, and the oxydated metal revived.

These circumstances, among others, led Dr. Gibbes to conclude that when hydrogen gas is produced by the affusion of water on red-hot metal, and the metal is at the same time oxydated, a decomposition of *fire* rather than of *water* has taken place; that the hot metal has parted with negative electricity, which, uniting with a small proportion of the water, has formed hydrogen gas; that a greater proportion of the water has united with the positive electricity, and entered, as oxygen gas, into combination with the metal. When the two gases are inflamed together, the spark attracts to itself, in due proportions, the two electricities contained in the two gases, which unite with explosion, and produce fire. The water with which they were before combined is of course deposited.

The reason why inflammable substances burn in oxygen gas, and not in hydrogen, Dr. Gibbes supposes to be, that negative electricity greatly prevails in all inflammable substances. Neither of the gases can be inflamed separately, because fire depends on the union of the two electricities; and such union cannot be effected unless both are present in due proportion.

Dr. Gibbes supposes that the further illustration of the effects of the two electricities, as chemical agents, will set aside some of the leading doctrines of the Lavoisierian theory, and afford an easy solution of certain phenomena which that theory cannot explain.

Æpinus' Theory of Electricity.

Mr. Æpinus, of the imperial academy of Petersburgh, has attempted to class the phenomena of electricity and magnetism in a mathematical method. In the course of his works he gives some views of the subject which are new and highly ingenious, and as some good judges suppose, calculated to surmount many difficulties, and to answer many questions, which occur in considering the Franklinian theory. The leading principles of his plan are comprehended in the following propositions.

1. Its particles repel each other, with a force decreasing as the squares of the distances increase.

2. Its particles attract the particles of some ingredients in all other bodies, with a force decreasing according to the same law, with an increase of distance; and that this attraction is mutual.

3. The electric fluid is dispersed in the pores of other bodies, and moves with various degrees of facility through the pores of different kinds of matter. In those bodies which we call non-electrics, such as water or metals, it moves without any perceivable obstruction; but in glass, resin, and all bodies called electrics, it moves with very great difficulty, or is altogether immoveable.

4. The phenomena of electricity are of two kinds: 1. Such as arise from the actual motion of the fluid,

from a body containing more, to one containing less of it. 2. Such as do not immediately arise from this transference, but are instances of its attraction and repulsion.—

These principles are applied at great length, and with a pleasing degree of precision, by the ingenious theorist, to the Leyden phial, and to the various phenomena of electric attraction and repulsion. It will be readily seen that Æpinus adopts, in substance, the theory of Franklin, of which, in some particulars, he presents new and more satisfactory views than the American philosopher. In the sixty first volume of the Philosophical Transactions, there is a dissertation by the Hon. Mr. Cavendish on this subject, which he considers as an extension and more accurate application of Æpinus's theory.

CHAP. III.

The Franklinean Theory of Electricity.

WE are now to give Dr. Franklin's theory of plus and minus, or positive and negative electricity, and adduce facts, to shew how far this theory will go to explain the different phenomena.

The Doctor supposed that all the operations in electricity, depended upon one fluid, *sui generis*, extremely subtile and elastic.—That there subsists a very strong repulsion between the particles of this fluid, in regard to one another, and as strong an attraction, with regard to other matter.—Thus one quantity of electric matter will repel another quantity of the same, but will attract, and be attracted by, any terrestrial matter that happens to be near it. The pores of all bodies are sup-

posed to be full of this subtile fluid; and when its equilibrium is not disturbed, that is, when there is neither more nor less of it in a body than its natural share, or than it is capable of retaining by its own attraction, the fluid does not manifest itself to our senses. The action of the rubber upon an electric disturbs this equilibrium, occasioning a redundancy of the fluid in one place, and a deficiency of it in another. This equilibrium being forcibly disturbed, the mutual repulsion of the particles of the fluid is necessarily exerted to restore it. If two bodies be both of them overcharged, the electric atmospheres repel one another, and both the bodies recede from each other, to places where the fluid is less dense.—For as there is supposed to be a mutual attraction between all bodies and the electric matter, such bodies as are electrified must go along with their atmospheres. If both bodies are exhausted of their natural share of this fluid, they are both attracted by the denser fluid, existing either in the atmosphere contiguous to them, or in other neighbouring bodies; which occasions them still to recede from one another, as if they were overcharged.

Dr. Franklin's theory has gained the greatest reputation, from the easy solution it affords of all the phenomena of the Leyden phial. The fluid is supposed to move with the greatest ease in bodies which are conductors; but with extreme difficulty in *electrics per se;* in so much that glass is absolutely impermeable to it. It is also supposed that all electrics, and particularly glass, on account of the smallness of their pores, do at all times contain an exceedingly great, and always an equal quantity of this fluid; so that no more can be thrown

into any one part of any electric substance, except the same quantity go out at another, and the gain be exactly equal to the loss. These things being premised, the phenomena of charging and discharging a plate of glass, or a Leyden phial, may be easily solved. In the usual manner of electrifying by a smooth glass globe or cylinder, all the electric matter is supplied by the rubber, from all the bodies which communicate with it. If it be made to communicate with nothing but one of the coatings of a glass plate, while the prime-conductor is connected with the other, that side of the glass which communicates with the rubber, must necessarily be exhausted in order to supply the conductor, which must convey the whole of it to the coating with which it is connected. By this operation, therefore, the electric fluid becomes almost entirely exhausted from one side of the plate, while it is as much accumulated on the other; and the discharge is made by the electric fluid rushing, as soon as an opportunity is given it by means of proper conductors, from the side which was overloaded to that which was exhausted.

It is not however necessary to this theory, that the same individual particles of electric matter which were thrown upon one side of the plate, should make the whole circuit of the intervening conductors, especially in very great distances, so as actually to arrive at the exhausted side. It may be sufficient to suppose, that the additional quantity of fluid displaces and occupies the place of an equal portion of the natural quantity of fluid, belonging to those conductors in the circuit which lay contiguous to the charged side of the glass. This displaced fluid may drive forwards an equal quantity of the same matter in the next conductor; and thus

the progress may continue, till the exhausted side of the glass is supplied by the fluid naturally existing in the conductors contiguous to it.

To account for the velocity with which electricity passes through good conductors, Dr. Franklin compares the electricity in the conductors, to a wire in the bore of a tube, which it exactly fills.—If one end of this wire be moved forward, every other part of it will move in the same direction, and at the same instant.

Dr. Priestley says, it may be thought a difficulty upon this hypothesis, that one of the sides of a glass plate cannot be exhausted, without the other receiving more than its natural share; particularly as the particles of this fluid are supposed to be repulsive of one another. But it must be considered, that the attraction of the glass is sufficient to retain even the large quantity of electric fluid which is natural to it, against all attempts to withdraw it, unless that eager attraction can be satisfied by the admission of an equal quantity from some other quarter. When this opportunity of a supply is given by connecting one of the coatings with the rubber and the other with the conductor, the two attempts, to introduce more of the fluid into one of the sides, and to subtract some from the other, are made, in a manner, at the same instant. The action of the rubber tends to disturb the equilibrium of the fluid in the glass; and no sooner has a spark quitted one of the sides to go to the rubber, than it is supplied by the conductor on the other; and the difficulty with which these additional particles move in the substance of the glass, effectually prevents its reaching the opposite exhausted side. It is not said, however, but that either side of the glass may give or receive a

small quantity of the electric fluid, without altering the quantity on the opposite side. It is only a very considerable part of the charge that is meant, when one side is said to be filled while the other is exhausted.

The above is the substance of the theory most generally received. It depends upon the following principles.

1. All terrestrial substances, as well as the atmosphere which surrounds the earth, are full of electric matter.

2. Glass, and other electric substances, though they contain a great deal of electric matter, are nevertheless impermeable by it.

3. This electric matter violently repels itself, and attracts all other matter.

4. By the excitation of an electric, the equilibrium of the fluid contained in it is disturbed, and one part of it is overloaded with electricity, while the other contains too little.

5. Conducting substances are permeable to the electric matter through their whole substance, and do not conduct it merely over their surface.

6. Positive electricity is when a body has too much of the electric fluid, and negative electricity, when it has too little.

Of these positions we shall now adduce those proofs, drawn from different facts, which seem in the strongest manner to confirm them.

I. "All terrestrial substances, as well as the atmosphere which surrounds the earth, are full of electric matter." The proofs of this are very easy. There is no place of the earth or sea where the electric fire may not be collected, by making a communication between it and the rubber of an electric machine. Therefore, con-

sidering that the whole earth is moist, and that moisture is a conductor of electricity, and that every part of the earth must thus communicate with another, it is certain that the electric matter must diffuse itself as far as the moisture of the earth reaches; and this may reasonably be supposed to be to the very centre.

The case is equally clear with regard to the atmosphere. The extract from Mr. Cavallo's journal, given in the chapter upon atmospheric electricity, is a sufficient proof that the atmosphere is full of electric matter.

II. "Glass, and other electric substances, though they contain a great deal of electric matter, are nevertheless impermeable by it." The principal arguments for the impermeability of glass by the electric fluid are drawn from the phenomena of the Leyden phial. It is very plain that there is, in charging this phial, an expulsion of fire from the outside, at the same time that it is thrown upon the inside. This appears from numberless experiments, but is most readily observable in the following. Let a coated phial be set upon an insulating stand, and the knob of another phial brought near its coating. As soon as sparks are discharged from the prime-conductor to the knob of the first, an equal number will be observed to proceed from its coating to the knob of the second. This is very remarkable, and an unphilosophical observer will scarce ever fail to conclude, that the fire runs directly through the substance of the glass. Dr. Franklin however concludes that it does not, because there is a very great accumulation of electricity on the inside of the glass, which discovers itself by a violent flash and explosion, when a communication is made between the outside and inside coatings. But it must be confessed, there is here no other

reason for concluding the glass to be impermeable, than the *probability* that the electric matter is accumulated on one side of the glass and deficient on the other.

Another argument against the permeability of glass and other electrics is, that coated phials can receive but a very slight charge when their outside coating is insulated, and this can be effected only with a very powerful machine.

III. "The electric fluid violently repels itself, and attracts all other matter." The proofs of this position have been so abundantly given in the course of this work, particularly in the chapter on electric attraction and repulsion, that we think it entirely superfluous to repeat them here.

IV. "By the excitation of an electric, the equilibrium of the fluid is disturbed, and one part of it is overloaded with electricity, while the other contains too little." This position must be considered as entirely hypothetical, as the manner in which the electric fluid is collected by the excitation of glass, or any other electric substance, has not yet been satisfactorily explained.

V. " Conducting bodies are permeable by the electric fluid, through the whole of their substance, and do not conduct it merely over their surface." Take a wire of any kind of metal, and cover part of it with some electric substance, as rosin, sealing-wax, &c. then discharge a jar through it, and it will be found that it conducts as well as without the electric coating. This, says Mr. Cavallo, proves that the electric matter passes through the substance of the metal, and not over the surface. A wire, adds he, continued through a vacuum is also a convincing proof of this assertion.

VI. "Positive electricity is an accumulation, or too great a quantity of the electric matter contained in a body; and negative electricity is when there is too little." This position, like the fourth, must be considered as hypothetical—the peculiar nature of the electric fluid not admitting of experiments to prove, or to disprove it.

APPENDIX.

NUMBER I.

A description of the Cement used for electrical purposes.

THE best cement for electrical purposes is made by melting two parts of rosin, two of bee's-wax, and one of brick-dust, or red ochre, together. This method of making cement is much preferable to that of rosin alone, as it is not so brittle, and at the same time it insulates equally well.

NUMBER II.

A Composition for Coating Cylinders or Globes.

THE most approved composition for lining glass cylinders or globes, is made with four parts of Venice turpentine, one part of rosin, and one of bee's-wax.—They must be boiled together for about two hours over a slow fire, and stirred very frequently; afterwards the composition is left to cool, when it is fit for use.

If a cylinder or globe is to be lined with this mixture, a sufficient quantity must be pulverised, and introduced into the glass; then by holding the glass near the fire, the composition is melted, and by a little skill may be spread over all its internal surface, to about the thickness of a wafer.—The glass, however, must be heated very gradually, otherwise, there is danger of its breaking in the operation.

NUMBER III.

To make the best kind of Amalgam for exciting Electrics.—

ANY metal dissolved in mercury or quick-silver will answer the purpose very well, thus two parts of quick-silver with one of tin-foil, or Aurum Mosaicum, have been used to advantage. But the most powerful composition for an amalgam, is zinc and mercury, in the proportion of one part of the latter, with five of the former, to which may be added a little bee's-wax or tallow, the proper way of preparing this amalgam is the following.—Let the quick-silver be heated, to about the degree of boiling water, and let the zinc also be melted in an iron ladle. Pour the heated quick-silver into a wooden box, and immediately afterwards pour the melted zinc into it likewise. Then shut the box, and shake it about for some time. You must now wait till the amalgam is cool, or nearly so, and then mix a little bee's-wax, or mutton-suet with it, by trituration.

NUMBER IV.

The preparation of electrical Paint.

THE electrician will very frequently have occasion to make use of paint, both for ornament, and convenience. We shall therefore describe a pigment, which, while it looks very well, insulates the instrument, and answers a variety of other purposes.—If a red colour is wished, let a piece of red sealing-wax be dissolved in a sufficient quantity of highly rectified spirits of wine, then

let the substance which you intend to colour be warmed, after which the paint may be laid on by means of a hair pencil. Care should be taken to render the instrument clean and dry, especially if it be a glass one.—Two or three coats of this paint, will generally answer every purpose. If a black colour is preferred, black sealing-wax may be used.

If the outside coating of a jar is desired to be coloured, common oil paint will do much better than that above described, for here insulation is not required; a covering of some paint or other is always necessary, in order to prevent the amalgam, which is often scattered about the table where the apparatus is placed, from corroding the tin-foil with which the jar is covered.

NUMBER V.

To make the Artificial Bolognian Stone.

"CALCINE some common oyster-shells, by keeping them in a good coal fire, for half an hour; let the purest part of the calx be pulverised and sifted. Mix with three parts of this powder, one part of flowers of sulphur. Let this mixture be rammed into a crucible of about an inch and a half in depth, till it be almost full; and let it be placed in the middle of the fire, where it must be kept red hot for an hour at least, and then set it by to cool: when cold turn it out of the crucible; and cutting or breaking it to pieces, scrape off, upon trial, the brightest parts; which, if good phosphorus, will be a white powder."

EPITOME

OF

GALVANISM.

CHAP. I.

A Short account of the discovery of Galvanism.

THIS part of our subject has been called *animal electricity*, by the greater part of those persons who have written upon it;—but this name seems to be improper; for, as an author of reputation on the subject, remarks, "it has by no means been proved that these phenomena depend either upon electricity or animal life." While this is the case, it is certainly best to distinguish this science by the name of its inventor Louis Galvani. He was an Italian, and professor of anatomy at Bologna, when he made the discovery of Galvanism, which was entirely accidental, as will appear in the following account.

Whilst Galvani was one day employed in dissecting a frog, in a room where some of his friends were amusing themselves with electrical experiments, one of them happened to draw a spark from the conductor, at the same time that the professor touched one of the nerves of the animal. The consequence was, that the animal's

whole body was instantly shaken by a violent convulsion. Astonished at the phenomenon, and at first imagining that it might be owing to his having wounded the nerve, the professor pricked it with the point of his knife, to assure himself whether or not this was the case; but no motion of the frog's body was produced. He now touched the nerve with the instrument as at first, and directed a spark to be taken at the same time from the machine, on which the contractions were renewed. Upon a third trial the animal remained motionless; but observing that he held his knife by the handle, which was made of ivory, he changed it for a metallic one, and immediately the movements took place, which never was the case when he used an electric, or non-conducting substance.

After having made a great many similar experiments with the electrical machine, he resolved to prosecute the subject with atmospheric electricity. With this view he raised a conductor on the roof of his house, from which he brought an iron wire into his room.—To this he attached metal conductors, connected with the nerves of the animals, destined to be the subjects of his experiments: and to their legs he fastened wires which reached the floor. These experiments were not confined to frogs alone. Different animals, both of cold and warm blood, were subjected to them; and in all of them considerable movements were excited whenever it lightened. These movements preceded thunder, and corresponded with its intensity and repetition; and even when no lightning appeared, the movements took place when any strong cloud passed over the apparatus.—That all these appearances were produced by the electric fluid was obvious.

Having soon after this suspended some frogs, from the iron palisades which surrounded his garden, by means of metallic hooks fixed in the spines of their backs, he observed that their muscles contracted frequently and involuntarily, as if from a shock of electricity. Not doubting that the contractions depended on the electric fluid, he at first suspected that they were connected with changes in the state of the atmosphere. He soon found, however, that this was not the case; and having varied, in many different ways, the circumstances in which the frogs were placed, he at length discovered that he could produce the movements at pleasure, by touching the animals with two different metals, which at the same time touched one another, either immediately, or by the intervention of some other substance capable of conducting electricity.

CHAP. II.

Of the Animals best fitted for Galvanic Experiments, of the Metals best calculated for making these Experiments, and of Conductors.

ALMOST every animal can be made to produce these muscular contractions by the Galvanic power, but those called *cold blooded* are the best. Thus *frogs* have been found the most convenient, both on account of their size and abundance. They also retain their muscular irritability to the Galvanic influence longer than most other animals, and it is asserted that strong convulsions can be produced in them many hours after the brain and spinal marrow have been destroyed; and

also that when pretty far advanced in the process of putrefaction they are capable of Galvanic excitement.

No contractions have been produced in animals killed by *corrosive sublimate*, nor in those which have been *starved* to death: but a very slight motion can be made to appear in those killed by *opium*, the *electric shock*, or *azotic gas*.

With regard to the metals used to effect these motions, almost any two will answer the purpose; but the most powerful are the following, viz.

		Gold.
Zinc		Silver.
Tin	in conjunction with	Molybdena.
Lead		Steel.
		Copper.

Those which have the most power are placed first; that is zinc and gold, will produce greater muscular contractions than tin and silver, or tin and gold, and so of the rest.

The process by which these wonderful appearances are produced consists in effecting, by means of the Galvanic apparatus, a communication between a nerve and a muscle, in any part of an animal body. The part of the animal upon which the experiment is to be performed is denominated the *animal arc*: and the Galvanic instruments which form the communication between the muscle and the nerve, are called the *excitatory arc*. This latter generally consists of three pieces; one fixed to the muscle, another to the nerve, and a third forming a communication between both. This last, called the *communicator*, may be made of the same metal with either of the others, or be different from both.

The best communicators or conductors, are the following.—The list begins with the most perfect.

Malleable platina.
Silver.
Gold.
Quicksilver.
Copper.
Brass.
Tin.
Lead.
Iron.
The human body.
Salt water.
Fresh water.

The metallic ores are not so good conductors as the purified metals, and their conducting power varies, according to the nature of the ores.

The metallic salts are tolerably good conductors.

Dr. Valli observed that human bodies are not all equally good conductors. Out of four persons in a company, he found that when two of them formed the circuit of communication between the nerve and muscles of a frog, the motions took place very readily. When the third person formed the circuit, the motions were very weak ; but that, when the fourth person formed the communication, no motion took place. This experiment, he adds, was often repeated with the same success. The effect however may be owing to the different dryness of the skin.

Vitriolic acid, and even alcohol, appear to conduct the Galvanic influence rather better than water.

The veins and arteries are not so good conductors as the nerves; for when a blood-vessel forms part of the circuit

of communication, the contractions will take place only when ramifications of the nerves are adhering to it, and if these be carefully separated, the motion will not take place. The same thing may be said of the tendons, the bones, and the membranes; for when either of those parts is separated from the body, and is introduced into the circle of communication between the muscles and nerves of a prepared frog, no motion will ensue; excepting, indeed, when those parts are full of moisture and in immediate contact with the nerve.

CHAP. III.

A Description of the Galvanic Trough and Pile.

PROFESSOR Volta's first contrivance for manifesting Galvanism in a more vigorous manner than had hitherto been done, was what he called a *couronne de tasses*. This consisted of tumblers of glass, half filled with water, or salt and water. These glasses or tumblers, were so placed that a metallic arc, in form of a C, could be fixed with one leg in one glass, and the other in the next glass. On one end of each arc, was fastened a small plate of silver or copper, and on the other end, a similar plate of zinc or tin. These plates were immersed in the fluid contained in the tumblers.—Thus in the water of every glass there was a plate of silver or copper, and another plate of zinc or tin. The metallic arcs were formed of any good conductor. When thirty or forty of these glasses were prepared, the experimenter put one of his hands into the fluid contained in the first glass, and the other hand into that in the last: when this was done a shock, something like the electrical one, was

experienced, and would recur as often as the circuit was interrupted and completed.

Mr. Volta remarks, that *alkaline solutions* are used to the most advantage when one of the metals is tin and the other silver or copper; but that where zinc is substituted for tin, salt water is preferable.

After this discovery, Volta invented a much more convenient instrument, which, besides other advantages over the former, was more powerful and less expensive. The instrument is called the *Galvanic pile*, and very often the *Voltaic pile*, from its inventor. It is made in the following manner—Take a number of circular plates of copper, or silver and an equal number of tin or zinc of the same dimensions. Next provide a like number of round pieces of paste-board, leather, or any other substance capable of retaining moisture for a considerable time. This leather, cloth or other substance, must be rather smaller than the metal plates and, when used, well moistened with salt and water. Now form a pile, by laying alternately the zinc over the silver, and, the cloth or other moistened substance, over the zinc; and so on successively.—By thus continuing the series to forty or fifty plates, a Galvanic pile will be constructed. If the pile is intended to be of any considerable height, it ought to be secured by pillars of varnished baked wood; or strong glass tubes.

To get the shock, one hand must touch the bottom, and the other the top plate.—The hands should be wet, as the cuticle or external part of the skin is a bad conductor.

Shocks may be received by applying the hands in this manner, as long as the leather, or other substance

interposed between the zinc and silver, continues moist; but as soon as it becomes dry the operation closes.

The drying of the substance was a great inconvenience in the Voltaic pile, and the inventor proposed, as a remedy for this, to station the metallic plates at a greater distance from one another, and to fill up the cells or intervals between them with a saline solution. Mr. Cruickshank, an English chemist at Woolwich, improved this construction.—His *trough* as it is called, is made thus.—

Get a wooden trough, made of hard baked mahogany, about thirty inches long, and four or five wide and deep.—On the inside let there be cut in the sides and bottom, and at equal distances from one another, as many grooves, as the number of plates required to be put into the trough;—the grooves of a size to admit the plates. The plates are to be cemented* separately to each of the grooves, so that no fluid can pass from one cell to another. In this instrument the plates are constructed by soldering a plate of zinc to one of copper. The zinc, or which is the same thing, the spelter of the shops, should be melted in a vessel which exposes but a small surface to the action of the air, otherwise it would absorb oxygen so rapidly as to be converted into the flowers of zinc.—The melted metal should be poured as soon as possible into a mould of the proper size, made of stone or brass.—It is not necessary that the plates of copper should be more than one tenth of the thickness of those of zinc.

The two plates are commonly soldered, not through their whole extent, but about one fourth of an inch

* For proper cement, see Appendix to electricity, No I.

from the edge; so that at the edge their union may be complete.

Care must be taken that all the plates be cemented to the trough in the same direction; so as to have the copper side of every plate opposite to the zinc side of the next.

The liquid employed to fill up the cells between the plates, is formed by diluting muriatic acid with water, in the proportion of one ounce of the former to a pint of the latter. When the trough is not in use, it should be emptied of this solution (which may be preserved for subsequent experiments, unless saturated with the metals) and then rinsed clean with fresh water.

This construction is preferable to the Voltaic pile, for experiments in which it is necessary to have the Galvanic action for a length of time. But for occasional experiments the pile is more convenient; as the trough, if suffered to remain long without the fluid, is apt to crack and separate the cement from the plates, which renders it necessary to cement them again.

When several batteries are required, they should be disposed in the same order as if they all constituted one trough, (observing through the whole series to keep the zinc surfaces constantly opposed to the copper ones,) and connected together by some metallic substance, such as a piece of sheet lead, or tin-foil, about half the width of the trough. Batteries combined in this way should all be, as nearly as possible, of the same power. For if a bad battery be united to five good ones, each of the same number of plates, the effect of the whole will be equal only to six times that of the bad one—as in electrical batteries, if three jars of different sizes be charged to-

gether, the whole charge will be equal to only three times that of the smallest jar.

CHAP. IV.

The Method of performing Galvanic Experiments with Frogs; with some conclusions drawn from them.

EVERY sensible heart must be shocked with the idea of torturing defenceless animals, merely to gratify an idle curiosity. The chapter which we shall now lay before the reader is founded entirely on the assertions of other writers upon this subject; to which, however, we have not the least doubt that the fullest credit is due. But we have not chosen to prove the veracity of their statements by our own experiments, believing that any small additional knowledge we might possibly have obtained in this way, would have been purchased at too great a price—the sacrifice of feeling and humanity.

Take a living frog, and after amputating the hind legs, (for they are the best, on account of the number of joints) let the largest nerve, called the *crural nerve*, be laid bare, and surrounded with a slip of tin-foil, or a piece of sheet lead—then lay a piece of zinc, or other metal different from that on the nerve, in contact with the neighbouring muscles; form a communication by another piece of zinc, or other good conductor, between the metal in contact with the muscle and the *armed* part of the nerve, and violent contractions will be produced in the limb.

There is another method of producing these convulsions, which has been preferred on account of its sim-

plicity.—It is by forming a communication between a nerve, armed as above, and an adjoining muscle, by a piece of zinc, without the assistance of a communicator.—This was one of the first methods of Galvanizing frogs, before the invention of the pile and trough. But since these discoveries, frogs have been made to show more violent convulsions.

We now proceed to relate some of the conclusions which have been drawn from the experiments on frogs.

1. The contractions produced in the limb of a frog are stronger the farther the metal is placed from the origin of the nerve.

2. When the metal has remained for some time on a particular part of the nerve the motion will cease; but it may be renewed by changing the position of the metal, and carrying it lower on the nerve.

3. Contractions may be produced in the prepared limb of a frog, by putting it in water, and then bringing two metals in contact with each other, at a short distance from the limb.

4. Only those muscles to which the nerves lead suffer contraction from the Galvanic influence.

5. When a contraction has taken place in any muscle, no other will follow while the metals remain in contact.—In order to renew the motions, therefore, the metals must be separated and joined again.

6. Galvanic excitement, instead of destroying the irritability of a muscle, gives it an additional support. Dr. Valli, an Italian physician, has fully confirmed this principle by the following experiment. "Having prepared the wing of a fowl, or the paw of a cat or dog, I subjected it to the customary trial. At the expiration

of half an hour, I armed the other wing of the fowl, or the other paw of the cat or dog, and had recourse to my exciting arc.—The latter wing or paw, however, did not give any sign of electricity, (for he conceived the motion to be occasioned by electricity,) while the parts which had been subjected in the first instance to the experiment, still continued in a convulsed and agitated state."

7. Galvanic experiments do not succeed so well in a room crowded with persons, as when only two or three individuals are present.

8. Galvanic contractions are more powerful the instant the animal is deprived of life, than some time after; and therefore more violent agitations can be produced in the living animal.

9. Volta concluded that Galvanism was generated by the metal, and not by the animal upon which he operated.

These are the principal remarks which we think worth noticing. If they do not content the reader, we must refer him to Wilkinson on Galvanism; where he will find a detail of almost every thing that happened in the Galvanic world till the time he wrote.

CHAP. V.

Various Experiments with the Galvanic Pile.

The first experiments which we shall mention were performed by Mr. Cruickshank, with the Galvanic pile. He employed plates of zinc and silver, 1.6 inches square, and the number of plates of both metals varied from forty to a hundred, according to the power required.

The lower end of the pile we shall denominate the *silver* end, because the plate at the bottom is of silver, and the upper end the *zinc* end, because the uppermost plate is of zinc. The first experiment of Mr. Cruickshank with the Galvanic pile, was upon water and silver wires. These wires were passed through corks, fitted into a glass tube filled with water, and projected about one third of the way, on both sides, into the tube; so that the space between the inner ends of the wires was one third of the length of the tube. One of the corks was made perfectly tight by cement. The tube was then placed upright in a tumbler of water, with the uncemented end downwards.

As soon as a communication was made between the extremities of the pile by the wires, small air bubbles began to ascend from the wire connected with the silver end, and a white cloud made its appearance at the wire proceeding from the zinc end.—The cloud gradually increased, assuming a darker colour, and at last it became purple, and even black. A few air bubbles were likewise observed upon this wire, which ascended from it; but when the pile acted well, a considerable stream of air could be perceived.—When this gas was examined, it was found to be a mixture of hydrogen and oxygen, in the proportion of three parts of the former to one of the latter. No great reliance, however, can be placed on the accuracy of this analysis. The wire proceeding from the zinc end, was found much corroded, and looked as if a portion of it had been dissolved.

Mr. Cruickshank supposed the cloud formed round the wire of the zinc end to be the muriate of silver, proceeding from the silver wire which had been some-

how dissolved, and afterwards precipitated in this state, by the muriatic salts contained in the common water.

The next experiment was with distilled water, a tincture of litmus, and silver wires, as before. The apparatus being adjusted in the manner above described, and one wire connected with one end of the pile, while the other touched the other end, gas immediately arose from both wires, but in greater quantity from the one connected with the silver plate. In a short time the whole fluid below the point of the wire from the zinc plate, became red, and the fluid below the wire from the silver plate, looked of a deeper blue. Distilled water tinged with Brazil wood, soon became of as deep a purple as could be produced by ammonia.—From the two last experiments, Mr. Cruickshank was led to suppose, that an *acid*, probably the nitrous, is produced at the wire connected with the zinc plate, and an *alkali*, probably ammonia, at the one connected with the silver end of the pile.

As hydrogen gas, whether heated or in its natural state, reduces metallic oxyds, Mr. Cruickshank resolved to subject solutions of metallic oxyds to the hydrogen gas which was produced by the pile.—The result answered his expectation, for in a minute or two after the communication was formed, fine metallic needles or crystals, something resembling a feather, were perceived round the wire connected with the silver plate.—The oxygen too which escaped from the metal, and that generated from the fluid used in the solution, was commonly pure, when an excess of acid was added to take up the alkali.—The acetite of lead and the sulphate of copper, were among the oxyds experimented upon, but whatever the metal was, the results

coincided. These experiments were made in a tube like the preceding ones.—A number of experiments were made by the same gentleman upon the *earths*, but we shall not detail them; we must content ourselves with some conclusions drawn from his observations.

1. Hydrogen gas, mixed with a small portion of oxygen and ammonia, is somehow disengaged at the wire communicating with the silver extremity of the pile; and this effect is equally produced, whatever the nature of the metallic wire may be, provided the fluid operated upon be *water*.

2. When metallic solutions are used, the same wire which separates the hydrogen gas, revives the metallic calx, and deposits it at its extremity, in its pure metallic state; in this case no hydrogen is disengaged. The wire employed for this purpose may be of any metal.

3. Of the earthy solutions, only those of magnesia and argill are decomposed by the wire: a circumstance which strongly favours the production of ammonia.

CHAP. VI.

Experiments on the deflagration of Metals by the Galvanic Pile.

THE pile with which these experiments were made consisted of thirty-six plates of silver, and an equal number of zinc ones, between which were interposed disks of flannel, moistened with a solution of the muriate of ammonia.—Each plate had a diameter of ten inches, or contained 78.58 square inches;—consequently the whole surface of silver in the pile, reckoning

only one side, was 2828.57 square inches, and that of zinc the same.

With this instrument, in December 1801, gold, silver, copper, tin, lead and zinc were deflagrated with surprising facility. The gold burned with a vivid white light, inclining a little to blue, and deposited an oxyd of a deep purplish-brown colour.—The silver gave a vivid flame of a greenish hue, and extremely brilliant. Its oxyd was of a blackish colour. The copper presented phenomena similar to those which attended the gold.—Lead gave a very vivid light, of a dilute bluish purple.—The tin afforded a light similar to that of the gold, but burnt with much less energy; probably because the leaves were thicker. The zinc gave a blueish white flame, which was edged, at the moment of contact, with red. It was more difficult to inflame than any of the preceding metals, but the leaves were likewise much thicker. The oxyds of the four last metals were not examined.

Water was poured upon the upper plate of the pile, so as to form a *standing pool;* and several pieces of the same kind of metals with those before experimented upon, were presented to the plate through this aqueous medium, and were deflagrated. They afforded a flame of the same colour as when they were brought to the bare plate.—A vapour was sometimes perceptible immediately after the deflagration, and was supposed to arise from a portion of water converted into steam by the intense heat.

It is very remarkable that the shocks taken from this pile, which produced such astonishing effects upon metals, could be received with but very trifling inconvenience, through the human body.

Besides these experiments, which were made by a society of gentlemen, a variety of others were performed, from which nearly the same conclusions were deduced.—Two other facts, however, deserve notice.

1. When metallic leaves are deflagrated in carbonic-acid gas, the flame is weak: but when in oxygen gas, the communication between the upper and under plates of the pile is no sooner formed, than the metallic leaves are destroyed with one sudden flash.

2. When metals are subjected to Galvanism in an exhausted receiver, they emit light but are not oxydated.

CHAP. VII.

Further Galvanic Experiments on Metals, and on other Substances.

IT is hardly necessary to mention, that every experiment made by means of the Galvanic pile may be performed, with equal success, with the trough. The experiments related in this chapter may be effected by the pile, but they cannot be done with the same convenience as when troughs are used. The battery* employed in these experiments consisted of sixty pieces of silver, and a like number of zinc, each two and a quarter inches square. The shock produced by this trough, by means of two metallic conductors, was distinctly felt in the shoulders, and the contraction or spasm was

* The pile and trough, are both sometimes denominated *Batteries.*

so violent, as to render the operator unable to hold the conductors, when in contact with the plates by which the trough terminated each way.—A sensation resembling that produced by hot water, was at the same time felt in the wrists and fore-arm.

A small steel wire, which was used for the conductor to form the communication, upon its contact with the plates, produced a vivid spark and bright scintillations.—When a piece of phosphorus was placed upon the end of this wire, and made a part of the circuit, it was instantly inflamed.

Another battery of the same size being connected with the one above described, gun-powder was fired, and gold-leaf deflagrated without any perceptible residuum—being probably volatilised by the heat occasioned by the experiment.

Mr. Davy, secretary of the Royal Society, placed a small piece of pure potash (which had previously been exposed to the atmosphere, so as to render it a conductor of the Galvanic fluid,) upon an insulated plate of platina, connected with the negative * end of a battery, of the power of two hundred and fifty plates, six inches by four, in a state of intense activity.—A wire communicating with the positive end, was brought in contact with the upper surface of the alkali. The whole apparatus was in the open air. Under these circumstances a vivid action was soon perceived.—The potash began to fuse at both points where the fluid acted upon it.—There was a violent effervescence at the upper

* Volta by the aid of his condenser of electricity, discovered that the two extremities of his pile were in opposite states; the zinc end was always plus or positive, and the silver end, minus or negative.

surface :—at the lower or negative surface there was no liberation of elastic fluid, but there appeared small metallic globules, very much resembling quicksilver. Some of these globules burned with an explosion and a bright flame, as soon as they were formed, while others remained which were merely tarnished; and finally a white film was formed over their surfaces, which was afterwards found to be pure potash.

Soda was acted upon in the same manner as potash, and exhibited the same results ; but its decomposition required a stronger action of the battery, or it was necessary that the soda should be in smaller pieces than the potash.

The metallic globules produced from the potash remained fluids in the open air, at the time of their production ; but those from soda, though fluid at the time of their formation, upon cooling, became solid, having much the lustre of silver. The alkalies could be made to produce metallic results in vacuo.

Since Mr. Davy's first experiments on this subject, several others have been made, much in the same manner, upon the earths. Messrs. Pontin and Berzelius, two Swedish chemists, have succeeded in obtaining metallic amalgams from lime, magnesia, strontites and barytes; but they could produce no such effect on alumine and silex. Mr. Davy however effected this, by a battery of 36000 square inches.—He also improved upon their other discoveries. He, by distillation, drove off the mercury from the amalgamated metals which they obtained from the earths, and procured a pure metal.

Ammonia was also found to contain a metal. This discovery inclines one to believe, that the air we breathe contains metal in a gaseous state, as azote, which is a

component part of ammonia, forms a large portion of our atmosphere.

When compounds, soluble in water, were put into water contained in agate cups, and subjected to the action of Galvanism, their decomposition was rapid.— A solution of the sulphate of potash, being put into two cups and Galvanised by fifty pair of plates, for four hours, the acid was found by itself in the cup connected with the positive end of the battery, and the alkaline basis in the cup communicating with the negative end. Similar phenomena took place in solutions of sulphate of soda, nitrate of potash, nitrate of barytes, phosphate of soda, sulphate, succinates, oxalate and benzoate of ammonia; also with alum. When muriatic salts were used, they afforded oxymuriatic acid. When metallic solutions were employed, metallic crystals and an oxyd were deposited on the negative wire, and a great excess of acid was found in the positive cup.— Strong solutions afforded signs of decomposition quicker than weaker ones.

We could enumerate a variety of similar experiments, but the limits of our work forbid it.

CHAP. VIII.

Experiments which may be performed without the assistance of the Battery.

To shew the Galvanic light.

PLACE a piece of zinc upon your tongue, and a piece of silver between your cheek and upper jaw; then move your tongue so as to bring the two metals in con-

tact with each other, and you will perceive a very curious sensation upon your tongue, accompanied by a cool sub-acid taste,* and at the same time you will see a *flash of light*, whether your eyes be open or closed. The sub-acid taste resembles, in a degree, that produced by electricity.†

To affect the Taste by means of Water.

Place a tin or pewter bason filled with clean water upon a silver mug: with both your hands, which must previously be wet with a solution of salt in water, grasp the silver vessel, and put your tongue into the water, taking care not to touch the tin or pewter vessel with any part of your body; you will now perceive an acid taste; which will be more sensible, if you withdraw your hands from the silver vessel while your tongue remains in the water, and then replace them.

* This sub-acid taste, is rendered much more distinct by an instrument invented by Professor Robinson, and described by him in a letter to Dr. Fowler, dated 28th May, 1793. It is made by placing alternately a number of small circular pieces of zinc, with as many pieces of silver of the same size, in the form of a *rouleau*. It is to be used by placing it laterally upon the tongue.

† With regard to the similarity between the taste of Galvanism and that of electricity, Dr. Fowler observes that he found considerable difference between them.—"Both (says he) are sub-acid, but as unlike each other, as the taste of vinegar is to that of diluted vitriolic acid."

This sensation, produced upon the tongue by Galvanism, is most distinct when the tongue is of its usual temperature, and the metals of the same temperature with it. When either the tongue, the metals, or both, are heated or cooled, as far as can be borne without inconvenience, scarcely any taste is produced.

To prove that Earth-Worms have a nervous system.

Place an earth-worm upon a plate of zinc, resting on a larger plate of silver.—The animal, as soon as it approaches the silver, seems to be repulsed by a painful sensation, and at last becomes fatigued by its repeated and fruitless exertions to make its escape, which nothing apparently prevents.

This evidently proves that the animal is provided with a nervous system, as experiments have proved that Galvanic irritation is excited only in the nerves.

CHAP. IX.

Some common Effects which are supposed to be occasioned by Galvanism,

WE have already remarked, that a sub-acid taste is perceptible when two different metals are applied to the tongue and fauces: it has also been found that Galvanism affects the taste, when two different *fluids* and a single metal are in contact with the tongue. Upon this principle a variety of known facts have been accounted for.—For example—It has long been observed that beer, cyder, &c. when drunk from a tin or silver vessel, were more palatable than when received from a vessel of glass, or any other substance not metallic. The supposed explanation of this, is as follows.—When the outer extremity of the vessel is applied to the under lip, rendered moist by the saliva, and the tongue is extended so as to be in contact with the liquid contained in the vessel, a Galvanic arc is formed, which produces the brisk and lively taste.

It has been supposed, by persons fond of this theory, that snuff, when taken from a metallic box, excites a more agreeable sensation than when taken from a box of tortoise shell, or leather.

The fact that a silver spoon becomes discoloured by being used for eating eggs, is familiar to every one. This, also, is attributed to the Galvanic action. By experiment, sulphur has been discovered in both the albumen and yolk of an egg.—The Galvanic combination is between the sulphur of the egg, the silver spoon, and the saliva; for no tarnish is produced on the spoon when it is immersed in either the albumen or yolk; and that part of the spoon which enters the mouth is most discoloured. In every Galvanic experiment, water is decomposed into its constituent parts, hydrogen and oxygen gases. These things being premised, the fact is easily accounted for.—The hydrogen, which before the operation is nascent in the water, (which holds the sulphur in solution) now readily unites with the sulphur, and forms sulphurated hydrogen gas, which produces the tarnish on the silver.*

We shall mention a few other common appearances, and leave the solution to the ingenuity of the reader.

When copper sheathing is fastened on a ship with iron nails, the nails, and particularly the copper, are found to be corroded about the places of contact.

Works of metal, the parts of which are joined by a solder of a different metal, are observed to tarnish about the places where the different metals meet. A seam which has been soldered so accurately that it cannot

* This is the explanation given by Mr. Wilkinson, but we think it probable that this effect is altogether chemical.

be perceived by the eye, may be discovered by passing the tongue over it.

CHAP. X.

The Effects of Galvanism on Vegetables.

THIS part of Galvanism has been particularly attended to by Humboldt, a German. He first observed the irritability of the vegetable fibre.

Remarking the great similarity of appearance between the substance of mushrooms and the muscular fibre, he wished to ascertain whether they possessed a similar power of contraction. He accordingly made a considerable number of experiments, from which he concluded that the different kinds of mushrooms, which in becoming putrid emit an animal insipid cadaverous smell, are as perfect conductors in the Galvanic chain as the organs of animals. His experiments likewise proved that they possessed irritability.

Mr. Humboldt afterwards directed his inquiries to the *manner* in which Galvanism acted upon the irritable fibre, which, as we have already mentioned, he first observed. These experiments, however, were unsuccessful. We shall not therefore relate them.

The effects of Galvanism on vegetation are supposed to be deleterious, as will appear from the following extract from the "Monthly Magazine."

"It often happens, that some of the limbs of fruit trees, trained against a wall, are blighted and die; while others remain in a healthy and flourishing state. This evil is, by gardeners, generally attributed to the effects of lightning. But, if this were the case, would not the violent

action of the electric fluid produce a laceration of the branch and stalk of the tree? No such effect is to be perceived. It therefore appears to me, that we must seek some other cause for this evil, and I flatter myself that I have discovered the real one.

A few years since, when Galvanism was first introduced to public notice, I constructed a pile, consisting of about one hundred plates of copper and as many of zinc, each about two inches square. Among other experiments, I applied it to the branch of a tender plant, (a species of the ficoides.) Having left it for about an hour, on my return I found the branch withered, and hanging close to the stalk. It immediately occurred to me, that Galvanism might be the cause of the above mentioned defect in wall fruit trees, occasioned by the oxydation of the nails, by which they are oftentimes fastened (for I conceive Galvanism to be produced, in a greater or less degree, by every metal passing into a state of oxydation.) Recollecting that the limb of a cherry tree in my garden had, nearly a year before, been fastened to the wall with an iron cramp, I instantly examined it, and found it dead; though, when fastened, it was a flourishing, healthy limb, at least an inch in diameter, and nine feet in length.

I have since examined several peach and nectarine trees; and wherever I discovered a limb dead, I invariably found that one or more of the nails which fastened it were in *contact with the bark*. A limb of a peach tree puzzled me for some time. It was dead, but I could not perceive that any of the nails were in contact with it, (the scraps of cloth being left pretty long.) After a narrow search, however, I found the mud, of which the wall was built, considerably stained with rust, im-

mediately under the branch: and on digging into the wall with my knife, I brought the hidden mischief to light.—It was part of a very large spike nail, and which lay about an inch below the surface.

On mentioning some of those circumstances to a friend, he observed, that about a year before, he had fastened some currant trees to a wall, with iron hooks. On examination, almost every limb so fastened, *was dead.*

The effect of the Galvanism in these cases will probably be found to be greater in rainy seasons, as the oxydation then goes on more rapidly than it does at other times."

Hence it appears that, in training fruit trees, wooden pegs or cramps, should be used instead of iron; or else, that care should be taken that the iron do not touch or come near to a limb.

CHAP. XI.

Of medical Galvanism.

GALVANISM, like electricity, has been applied to the human body, for the purpose of removing complaints, and apparently with equal success.

The ingenious Galvani, immediately after his discovery of Galvanism, (or as he called it, *animal electricity*,) attempted to explain the causes of several diseases by it. Thus in a complaint where there was a total loss of contractile power, as the paralysis, he ascribed the cause to the interposition of a non-conducting substance, which prevented the passage of the Galvanic fluid from the nerve to the muscle, and from the

muscle to the nerve. "If artificial electricity (says he,) be conveyed to the head, the nerves or spinal marrow, by means of the conductor of the Leyden phial, paralysis, apoplexy, and even death, will be induced, according as the phial is charged with a greater or less quantity of the electric fluid.—If such effects result from *common* electricity, may it not be presumed that a sudden afflux of *animal* electricity towards the brain, may be productive of the most fatal consequences."

But omitting, as wholly conjectural and unsatisfactory, all *theories* relating to the effect which Galvanism has upon the animal œconomy, we shall proceed to relate known facts, and the method of applying Galvanism for the relief of certain morbid affections of the human body.

The general mode of operating with Galvanism, is to apply small portions of it at first, and gradually to increase the shock, as circumstances may dictate. It has been customary to remove the cuticle (by means of a blister or otherwise,) from the parts of the body to which the wires, communicating with the two extremities of the battery, are to be applied. This method, which was adopted because the cuticle is a very bad conductor, gave excruciating pain to the patient. Mr. Wilkinson has found it unnecessary, as by moistening the parts, and applying pieces of gold-leaf or Dutch-metal, he has succeeded in producing the desired effect. During an operation, one of the conducting wires should be kept in contact with one of the metallic leaves, while the other conductor is to be removed, immediately after it has been brought in contact with the other metallic-leaf—and then replaced and removed successively.

The negative wire of a battery is the most powerful, and it is necessary in some cases to attend to this fact.

In a short time after Galvanism has been applied to a part of the body, a redness becomes perceptible about the part; and if the application be continued too long, vesications and ulcerations will be produced. These symptoms are a little troublesome at first, but do not require any particular treatment for their cure.

Galvanism should be applied twice in twenty four hours, otherwise it is supposed the intervals would be so long, as to prevent any good effects which might arise from it.

We shall now enumerate some disorders in which Galvanism has proved beneficial. In *paralytic affections* it has afforded considerable relief.—Two instances of *mental derangement* are recorded by professor Aldini, nephew to Galvani, in which its effects were truly surprising.—One of them afforded an instance of a gradual diminution of the mental energies, which ultimately sunk into stupidity. The other was of an opposite nature:—the system was in a state of violent excitement, and the patient raving and unmanageable.

In *rheumatism*, *spasmodic affections*, and *deafness*, where it does not arise from a natural defect in the organ, Galvanism has been applied generally with advantage. But the most astonishing effects of this wonderful principle have been displayed in cases of *suspended animation*. Mr. Humboldt made the first experiments relative to this part of our subject, on apparently dead linnets. He put a piece of zinc into the bill, and thrust a sharp piece of silver into the bird, near the other extremity of the body—he then formed a com-

munication between the two, by an iron wire. "What (exclaims he) was my surprise, when I perceived, the moment the contact took place, the linnet open its eyes, stand erect on its feet, and flutter its wings; it again breathed during six or eight minutes, and then expired tranquilly."

Galvanism is now applied to persons apparently dead, from drowning, hanging, or exposure to noxious gases. In such cases, the body should be divested of its clothing, and placed in a warm bed nearly approaching the natural temperature, and at the same time slight Galvanic shocks should be passed through the body, in such a direction as to affect the heart.—Thus by combining this, with the usual means, the most advantageous consequences may be expected. It may be laid down as a principle, that, in all cases where animation is suspended, and the principle of irritability not destroyed, the stimulus of Galvanism and electricity, if prudently employed, may rouse the dormant energies of vitality, and restore the system to its natural state of activity.

CHAP. XII.

The Identity of Galvanism with Electricity considered.

IT has been supposed by many, that the phenomena of Galvanism and electricity depend upon the *same* cause. Others, however, controvert this opinion, and affirm that Galvanism is a fluid *sui generis*. That there is a great similarity between some of the phenomena of Galvanism and those of the electric fluid, is

evident; but this analogy cannot be traced in every instance.

It is not our province to enter into this controversy; we shall only relate a few facts upon which it is founded, and leave the speculative reader to draw from them his own conclusions.

Facts which seem to indicate that Galvanism and Electricity are the same Fluid.

Both Galvanism and electricity exhibit light, in their passage from one conductor to another, through an intervening space of air.

Both affect an electrometer.

The deflagration of metals may be produced by either.

Electricity, as well as Galvanism, produces muscular contractions in animals, a short time after death.

Facts in which Galvanism and Electricity differ from each other.

Some *good* conductors of electricity are not good conductors of Galvanism; as was shewn by Dr. Fowler.

The manner of exciting Galvanism is different from that of exciting electricity;—the former being collected most copiously from *conductors*, and the latter from *non-conductors*.

The electric fluid affects the sense of smelling—but no smell has ever been observed from Galvanism.

The electric shock operates on the body by a sudden and percussive effect—while the one which follows

the Galvanic process seems to arise from a constant current, attended by a jarring and tremulous sensation.

In the decomposition of water by Galvanism, hydrogen gas is formed at one of the wires, and oxygen at the other. In that by electricity, both gases arise from the same wire.

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